Ecosystem Services Approach Pilot on Wetlands

Integrated Assessment Report

October 2011

Government of Alberta

Table of Contents

Report Acknowledgements 3

Ecosystem Services Pilot Acknowledgements of Contributors 3

About this report 4

Executive Summary 5

1.0 Introduction 10

2.0 Understanding the Context for a Place-based ES Assessment: Results of Research on the Case Study Area, Drivers of Change and Stakeholder priorities 18

3.0 Ecosystem Service Assessment Results 26

4.0 Discussion 66

5.0 Conclusions, Recommendations and Next Steps 77

Appendix A: References 84

Appendix B: Glossary 89

Report Acknowledgements

Editors
Dr. Ciara Raudsepp-Hearne, Geneva Claesson and Gillian Kerr

Report Contributors
Anish Neupane, Brett Johnson, Dr. Ciara Raudsepp-Hearne, Courtney Hughes, Eric Beveridge, Geneva Claesson, Gillian Kerr, Dr. Glenn Brown, Justin Wilkes, Krista Tremblett, Tom Klavins and Yihong Wang

Ecosystem Services Assessment Consultants
Ducks Unlimited Canada, Dr. Irena Creed and her team, O2 Planning and Design, Dr. Paul Adamus, Rob Bewer

Reviewers
ES Pilot Team: Vic Adamowicz, Erika Almási-Klausz, Shari Clare, Rob Dunn, Dan Farr, Johannes Förster, Shane Gabor, Brian Hills, Arnold Jantz, Tom Klavins, Florence Landsberg, Scott Millar, Karen Raven, Lana Robinson, Christian Schleyer, Tracy Scott, Morris Seiferling, Rob Simieritsch, Fiona Slessor, Chris Spytz, Carolyn Tralnberg and Barry White

External: Tom Goddard, Marcus Lee, Joanne Little, Nicolas Lucas, Shane Patterson, Heather Sinton and Jonathon Thompson

Special thanks to Lana Robinson for conducting an early report review.

Ecosystem Services Pilot Acknowledgements of Contributors

There were over 40 people that formed the Ecosystem Services Approach Pilot on Wetlands. Some left the pilot before it was completed and some joined mid stream. It is important to recognize the people that committed in various ways to the successful completion of this work

Angele Vickers, Anish Neupane, Arnold Jantz, Barry White, Blake Mills, Brian Hills, Brett Johnson, Carolyn Tralnberg, Chad Willms, Charles Iceland, Dr. Chokri Dridi, , Christian Schleyer, Chris Spytz, Dr. Ciara Raudsepp-Hearne, Courtney Hughes, Dan Farr, Eric Beveridge, Erika Almási-Klausz, Fiona Slessor, Florence Landsberg, Geneva Claesson, Gillian Kerr, Dr. Glenn Brown, Heidi Wittmer, Joanna Johnson, Johannes Förster, Jonathon Thompson, Justin Wilkes, Karen Hughes-Field, Karen Raven, Kerri Charest, Kim Shade, Krista Tremblett, Lana Robinson, Dr. Lee Foote, Luis Leigh, Dr. Marian Weber, Meghan Snowdon, Mona Keffer, Morris Seiferling, Rob Dunn, Rob Simieritsch, Rifaat Hammad, Rebecca Reeves, Scott Millar, Shane Gabor, Shari Clare, Tom Klavins, Dr. Tomas Nilsson Tracy Scott, Valerie Sexton, Dr. Vic Adamowicz, Wanjing Hu, Yihong Wang

About this report

The Ecosystem Services (ES) program within Alberta Environment and Water (AEW) has been advancing the use of an ES approach within the Department and Government of Alberta since 2007. The Ecosystem Services approach Pilot on Wetlands (ES pilot) is part of the department's 10-year ES road map; its completion and results are considered a progression in understanding and applying an ES approach to support decision making.

Important to note for the reader, the combined complexity of ecosystems and interactions with people, including the functions, services and benefits they provide, is a challenging new arena for science. **The work of this pilot team and the results presented are a step forward in building an understanding and knowledge of ES and using an ES approach; however we caution the reader that there is more work to be done, both in Alberta and globally to strengthen the meaning and use of ES approach results.** Therefore, there are limitations in the information presented. The results need to be considered advancements in ES knowledge in Alberta, but considered 'pilot results' with caveats. Based upon advice and experience of international experts it is understood that the work to assess ES within a strong policy context, and using knowledge from multiple disciplines, is leading edge, and attempts were made to ensure the pilot and results presented are credible, legitimate and policy relevant. Globally, there are no international standards, methods or processes for conducting an ES assessment.

The report is laid out in five sections and includes an Executive Summary. The Executive Summary provides a high-level overview of the pilot context, a summary of the assessment results, links to pilot objectives and key conclusions and recommended next steps for an ES approach in Alberta. Section 1 provides an introduction to ES and an approach used to frame the ES Pilot. Section 2 provides context for the case study area where the pilot was deployed, and the issue that the pilot focused on. Section 3 contains the results from the assessment. Section 4 provides the key findings related to the issue identified, and assesses the results against the outcome and objectives of the pilot. It also summarizes a number of other learnings' from the pilot implementation process. Section 5 provides conclusions. It also provides potential recommendations and next steps to be considered for the Alberta Environment ES program and ES road map.

There are a number of complementary deliverables prepared for the ES pilot. Other reports include: an ES approach Report that focuses on methods and process, a Project Evaluation Report, a Summary Report for Decision makers and a Summary Report for a general audience. In addition there are a number of technical reports including: reports for various components of the biophysical assessment, a socio-economic report and the socio-cultural report. As such, a detailed overview of the methods used is not included in this report. The combined deliverables for the ES pilot together provide all the key elements for understanding the results, the methods, project evaluation and the learning's from the Ecosystem Services Approach Pilot on Wetlands that can support future work on ES in Alberta and internationally.

Executive Summary

Ecosystem services ('ES') are the benefits that nature provides to people. Some ES benefits, such as crops, are familiar and tangible; however, other ES, such as water filtration and carbon storage, are hard to observe and are underestimated or unaddressed in decision making. Ecosystems provide innumerable services that are underrepresented or absent in most economic development decisions; however, these services contribute to development objectives (e.g., scenic quality of the land) and to realizing quality of life goals. Identifying and understanding many of the services from wetlands can provide more information to decision makers, which may help to prevent unintended consequences from development decisions.

Wetlands, and the regulatory approvals process for residential subdivision development in southern Alberta, were the focus for the ES pilot. Wetlands are an integral component of Alberta's diverse landscapes and provide a wide variety of ES. For example, if managed properly, wetlands can provide water filtration and groundwater recharge, contribute to flood prevention, and provide habitat for numerous species of interest to naturalists and hunters alike. Many wetlands also have important socio-cultural value because they provide recreational, heritage and scientific/educational opportunities. As improvements are made in describing and valuing the benefits of ES, decision makers can better understand how their decisions might change (positively or negatively) the condition, quality and/or quantity of ES that could have an impact the well-being and quality of life of Albertans, and the businesses that operate in the province.

The outcome for the pilot was established as the following: "the development and operationalization of an ES approach to provide a tool to enhance decision making". The ES approach developed for the Alberta context provides a framework to help identify and quantify - qualitatively, quantitatively and monetarily - the benefits provided by wetland ecosystems. In addition to the outcome, two objectives were established by the project steering committee, with a third captured from the ES pilot project charter:

- Test and demonstrate how an ES approach can be used to support decision making by explicitly demonstrating the trade-offs between development and ES benefits provided by wetlands;
- Support wetland management in the province by providing additional information to support potential compensation decisions related to land-use development; and
- Identify information and capacity gaps for ES assessment to support future ES work.

Meeting these objectives involved conducting various assessments on wetland ES to address gaps identified by wetland approval managers at Alberta Environment, the City of Calgary and Rocky View County (a.k.a., the 'decision makers') in their application of the wetland approvals process and the wetland mitigation hierarchy (which includes compensation). The decision makers helped the ES pilot team to identify, frame and prioritize key gaps in the wetlands approval process to focus the pilot assessment work. The following represent the refined gaps that were used to design the project:

1. **There is insufficient evidence to support avoidance, minimization and compensation decisions on wetlands.**
2. **There is insufficient consideration of cumulative effects and long-term consequences of decision making.**
3. **There is limited ability to communicate the 'values' of wetlands.**

The pilot focused on an area covering 274 square kilometres encompassing an eastern portion of the City of Calgary, an area of Rocky View County and the Town of Chestermere. The area was chosen because of the large number of wetlands and current land use pressures where residential development is having an impact on the ES that are supplied by the landscape.

The case study area features (6,400+) wetlands ranging in size from less than 0.1 hectare to over 10 hectares. However, while the number of wetlands has increased 18 per cent since 1962, wetland area has decreased by 24 per cent. This translates into a **total loss of 7.7 square kilometres of wetlands** between 1962 and 2005. Nested in the South Saskatchewan Region, historic landscape change in the region and the case study area has been primarily driven by population growth and agricultural expansion. More recently, urban expansion has led to new changes on the landscape, including an increased percentage of impervious surfaces, stormwater pond creation and new micro-climactic conditions.

Through a series of working sessions, the ES pilot chose three ES as being the top priority for greater understanding: **water storage/supply, flood control** and **water purification/quality**. These ES were chosen for in-depth assessment along with **carbon storage**, which was included because carbon storage opportunities feature importantly as part of the provincial Climate Change Strategy and related regulations. Additional ES (e.g., pollination, cultural ES) were described and investigated in terms of their contributions to local society, but their condition (e.g., quality, quantity and distribution) was not assessed in detail across the entire study area.

The ES pilot engaged a broad selection of stakeholders, including ES beneficiaries, in the pilot. They **identified cultural ES as high priorities for management** in survey responses and workshop discussions. In particular, aesthetic enjoyment and science and education opportunities were identified as 'high value' benefits provided by wetlands. Biodiversity was also identified by multiple stakeholders as being of high importance, however, biodiversity is considered to be a necessary underlying condition for the production of ES but not an ES itself.

The information generated by the ES pilot provides a baseline of knowledge about wetland ES in the study area that decision makers can apply in wetland approvals decisions. Highlights from the assessment results include:

- ES benefits are context specific, as they relate as much to how the environment is used and valued as to how services are produced by ecological processes. There are a number of beneficiaries of different ES at different scales.

- The total water storage capacity of all wetlands in the study area was estimated to be **36.3 million cubic metres**. This represents a volume of water greater than the combined total storage capacity of the Glenmore Reservoir and Lake Chestermere.

- In the fall of 2007 and 2009, seasonal and dry annual conditions resulted in an estimated total wetland volume of **14.3 million cubic metres** or **39.4 percent** of total water storage capacity.

- An analysis of water storage capacity by Stewart & Kantrud (S&K) wetland class showed that because there is a large number of wetlands that are Class I or II, their contribution to water storage on the landscape is substantial, even if individually they hold less water than Class III-V wetlands.

- The estimated **total storage capacity lost due to wetland drainage between 1965 and the present is 9.2 million cubic metres**. This represents a **20 per cent decrease** in available water storage capacity in the study area.

- All wetlands in the case study area contribute to flood control. There were no clear trends found for flood control values across either S&K or size classes, suggesting that **high or low flood control depends more on landscape context than on class or size of wetlands**.

- The cost of replacing natural wetlands with built infrastructure was estimated from the total area of engineered wetlands that would be required to provide the same flood control services that are currently supplied by natural wetlands. A **replacement cost of all wetlands was estimated at about $338 million**. This corresponds to an estimated **$2 million per year in economic losses** when the historic rate of wetland area loss is applied.

- The estimated cost of restoring all wetlands on the landscape would be **$43 million**. This corresponds to an estimated **$257,250 per year in restoration costs** if the historic rate of wetland loss is applied (0.6 per cent between 1960's and 2005).

- The majority **(87 per cent)** of wetland complexes within Shepard Slough have **a medium to high capacity to purify water, estimated using a water purification model.**

- The estimated **loss of soil organic carbon between 1962 and 2005 is 44,144 Milligram (Mg) (89 Mg hectares^{-1})**. This is equivalent to an **emission of 161,832 Tonnes of Carbon Dioxide equivalent (CO_2 e)**.

- Applying the provincially relevant Alberta Tech Fund value of $15 /tonne of Carbon Dioxide equivalent, the economic value of carbon storage in the case study area would amount to **$16.7 million**.

- Recreation survey results showed the potential value for recreation from wetlands in the study area to be approximately **$4,390,000 per year.** This result is based on an estimate of 114,685 wetland visitors each year, each spending $38.28 for a day trip.

- Results of a hedonic pricing valuation identified a clear relationship between property value and distance/adjacency to wetlands. If the property is adjacent to a wetland, the value of the house increases by **$4,390 - $5,136**.

The results from the assessment allowed the ES pilot to address the gaps in the wetland approvals process. For example, the pilot identified that many of the ES provided by wetlands are currently excluded in current requirements for municipal Biophysical Impact Assessments and Wetland Impact Assessments and as such, multiple ES are absent from decision making. In addition, wetlands provide multiple ES simultaneously, which is important when considering avoidance or compensation options for wetlands. Importantly, the ES pilot demonstrated that although a wetland is degraded, it could be high functioning and provide a number of ES and benefits. This information could inform trade-offs and also help to highlight 'hot spot' areas to avoid in the planning process.

A rapid assessment site-level tool tested in the pilot provided immediate benefits for the wetland approval process. It offers a tool for decision makers, complementary to the pilot's ES approach, to develop information about the ES provided by individual wetlands. It can provide objective information on the values and functions of small and temporary wetlands that are often dismissed as unimportant when compared to large and visually appealing wetlands with permanent open water zones. The tool, Wetland Ecosystem Services Protocol for the United States (WESPUS), requires modification for the Alberta-context, however it provides an opportunity to shape the process of avoidance, mitigation and compensation in a manner that may better reflect public values associated with wetlands. If a wetland approval writer does not select avoidance or minimization, approval writers could use this tool to determine appropriate compensation and restoration requirements.

The ES pilot allowed the decision makers to explore information on the cumulative effects of wetland loss and potential consequences of long term decision making. For example, the loss of wetlands in the case study area over the past 50 years has led to a substantial cumulative loss of multiple ES including flood control, water purification/ filtration and water storage. In particular, areas that have historically seen large losses in water storage are more likely to also experience changes in soil moisture, micro-climate, flood control and other ES because water storage is fundamental to the delivery of other ES benefits.

An important contribution of the ES pilot was the ability to demonstrate multiple 'values' of wetlands in the case study area. For example, the results demonstrated that all classes of wetlands in the case study area contribute benefits, regardless of size and magnitude of current degradation. Even small wetlands provide essential services such as water purification and flood control, sometimes in conjunction with adjacent and connected wetlands. To complement typical aquatic environment and hydrology information used by decision makers, the pilot incorporated socio-cultural information on how people value different ES in the study area. Information about local people's perceptions of why wetlands are important can directly inform wetland approval decisions, as this is new information about the value of wetlands to society. Studies conducted for the pilot demonstrate that even the most abstract cultural benefits (e.g., heritage benefits) are consistently rated as of 'high' or 'medium' importance to people.

The pilot demonstrated that an ES approach can provide a systematic way to assess ES benefits and impacts, and explore the trade-offs associated with development decisions that incorporate more than typical environmental and/or economic information. Given the novelty of the assessments activities, a number of recommendations have emerged to further advance the ES road map:

- There is a strong need to examine how the local and regional assessment tools applied can be streamlined to improve efficiency and cost effectiveness. Many assessment activities occurred in isolation, and while the pilot team made efforts to integrate activities and align results, it is recognized that the pilot fell short of the intention to conduct a holistic and integrated ES assessment. Improved integration during the design phase can improve project delivery, communications and the final products, which can reduce costs.
- The data, information and resources needed to complete ES assessments, particularly the biophysical assessment, was significant. It will be important to assess what scale and level of importance a policy or plan is to warrant the monetary and staff costs of doing an ES assessment.
- The uptake of WESPUS is a 'low hanging fruit' to integrate ES into the wetland approvals process and other Government of Alberta activities as other ES assessment methodologies mature. With thirty-years of testing and refinement already, the WESPUS approach requires minor modifications for the Alberta context. Given the popularity of WESPUS, it will be essential to build on the momentum generated in this pilot.

The concept of ES is still in its infancy, but has been recognized globally as a useful tool for communicating the value of sustainable landscape management to support development and the long-term well-being of people. Ecosystem Services are becoming increasingly important for governments and business leaders to address in decision making. The Government of Alberta took a leadership role in advancing the ES road map and completing a pilot project to explore the incorporation of ES into an actual policy gap identified by municipal and government wetland approvals writers. This report represents the Integrated Results from the ES assessments and provides key findings and uses for the information generated. The ES pilot reports make up the platform from which to move forward on a number of opportunities to further improve understanding of ES, build capacity to assess ES, and provide more complete information to decision makers to improve the outcomes of their decisions.

1.0 Introduction

1.1 Overview of the Ecosystem Services Pilot

Ecosystem services (ES) are the benefits that nature provides to people. Ecosystem services provide innumerable services that are underestimated in most economic development decisions; however, these services contribute to development objectives (e.g., scenic quality of the land) and to realizing quality of life goals. For example, the flood control service of wetlands can help to protect homes, infrastructure and communities during extreme weather events.

The Ecosystem Services Approach Pilot on Wetlands (ES pilot) was initiated in 2010 as one of the short-term and medium-term goals of Alberta Environment and Water's Road Map for Ecosystem Services in Alberta[1]. The road map articulates a strategy for integrating ES into Alberta Environment and Water's (AEW) governance, policy and programs (Text Box 1): The ES pilot contributed to the short-term goals of enhanced appreciation and understanding of ES in policy, planning and decision making.

The ES pilot focused on assessing the benefits that people acquire from wetlands in a qualitative, quantifiable and comparable way. The ES pilot was conducted in an area encompassing the east part of the City of Calgary, Rocky View County and the Town of Chestermere, where residential sub-division development is having an impact on the ES that are supplied by the landscape.

The ES pilot, and the concept of ES, supports other important work in Alberta, including the Land-use Framework and regional plans, the interim provincial wetland policy (Government of Alberta, 1993), Rocky View County (www.rockeyview.ca) and the City of Calgary (www.calgary.ca) polices on wetlands and riparian areas, and the Institute for Agriculture, Forestry and the Environment's (IAFE) work on ES and innovation in the forestry and agriculture sectors (Kennedy, 2010).

Textbox 1 – AEW's ES Road Map sets out the goals and path forward to support integration and adoption of the ecosystem services approach. Adopting an ecosystem services approach will support and enable AEW's work on cumulative effects management, policy development, planning, and decision making.

Short term goal (now-1 yr): An enhanced appreciation and understanding of an ES approach to supporting policy, planning, and decision making is identified and supported by all levels of relevant management in AEW.

Medium term goal (now-3yrs): The importance of ES is better understood and the department has increased its capacity for quantitative measurement of ES on the landscape to support policy, planning, and decision making within AEW.

Long term goal (3-7yrs): A strong qualitative and quantitative capacity exists within the department to enable the ecosystem services approach to be common practice within AEW's policy, planning, and decision making processes.

The scope of the ES pilot was determined in the fall of 2010 through discussions with wetland experts, regional government staff and biological/ecological/economic experts from AEW, other ministries and other institutions. The outcome for the pilot was established as the following: “the development and operationalization of an ES approach to provide a tool to enhance decision making”. The pilot charter originally had five objectives but these were modified as an understanding of the pilot needs and constraints progressed. In addition to the outcome noted above, the Steering Committee agreed to the following objectives:

---

[1] For information on the AENV Ecosystem Services Road Map, please contact AENV at Gillian.kerr@gov.ab.ca.

- Test and demonstrate how an ES approach can be used to support decision making by explicitly demonstrating the trade-offs between development and ES benefits provided by wetlands; and

- Support wetland management in the province by providing additional information to support potential compensation decisions related to land-use development.

Additionally the ES pilot team deemed it important to also identify information and capacity gaps for ES assessment to support future ES work, and as such, this third objective was also established.

Meeting these objectives involved developing biophysical, socio-cultural and economic information on wetland ES to address gaps identified by wetland approval managers at AEW, City of Calgary and Rocky View County (a.k.a. the ‘decision makers’) in their application of the wetland approvals process and the wetland mitigation hierarchy (which includes compensation).

1.1 Considering ES in wetland management

Wetlands are an integral component of Alberta’s diverse landscapes and provide a wide variety of ES. For example, if managed properly, wetlands can provide water filtration and groundwater recharge, contribute to flood prevention and provide habitat for numerous species of interest to naturalists and hunters alike (*Water for Life*, 2008). Also, many wetlands have important socio-cultural value because they provide recreational, heritage and scientific/educational opportunities. Some benefits, such as crops, are familiar and tangible; however, other ES, such as water filtration and carbon storage, are hard to observe and are underestimated or unaddressed in decision making. Identifying many of the services from wetlands can provide more information to decision makers which may help to prevent unintended consequences from development decisions (WRI, 2008).

The ES pilot was focused on prairie pothole wetlands in an area of southern Alberta. These wetlands are under considerable pressure from population growth and land-use development such as urban expansion, agricultural drainage, natural resource extraction and road construction. Approximately 65 per cent of slough/marsh wetlands in the settled areas of Alberta have been significantly altered or have disappeared. Of this area, the estimated annual loss of wetlands is 0.3 per cent to 0.5 per cent[2] (Turner et.al., 1987; Watmough et.al., 2002).

Wetland loss has been particularly acute in the Calgary municipal area due to residential, commercial and industrial development that often entails draining and filling in wetlands. It is estimated that Calgary many have lost as much as 90 per cent of its wetlands since pre-settlement times (Calgary State of the Environment Report, 2006).

---

[2] An annual rate of wetland loss in the case study area was not available.

Climate change in the Canadian prairies, particularly increasing temperatures and decreasing precipitation, also represents a threat to wetlands which includes the potential to exacerbate dry conditions and reduce the amount of water stored on the landscape (Sauchyn *et al.*, 2007). Understanding how diverse pressures on wetlands impact their ability to provide ES is important for informing trade-offs in development decisions.

When wetlands are altered, drained or degraded a cost can be incurred by society if ES that were previously provided at no cost by wetlands may need to be replaced by built infrastructure such as stormwater ponds. Examples of costs[3] include:

- increased water treatment costs;
- increased illness and health care costs stemming from water contamination;
- irrigation water shortages;
- increased stormwater infrastructure costs, including construction, operations, maintenance and monitoring;
- threats to biodiversity, which is the foundation for many ES;
- increased carbon emissions from the wetlands to the atmosphere contributing to climate change;
- increased insurance costs due to flooding;
- decreased property value due to degraded aesthetic qualities;
- decreased recreational opportunities; and
- decreased revenues from tourism activities associated with healthy ecosystems, and aesthetic and spiritual value losses.

These costs are not systematically accounted for in development decisions because they are not known or not part of decision-making processes. There can be also considerable time lag between the impact of a development decision and the effects to the function of wetland ecosystems, making such incorporation into decision making difficult. In the case study area, these types of costs are not currently addressed in the residential development approval regulatory process.

Building ES considerations into development approvals, land-use plans and compensation requirements can lead to increased human well-being, including enhanced economic benefits, and can contribute to risk management (WRI, 2008). The lack of incorporation of ES into land management and regulatory approvals decisions could lead to risks to the well-being of individuals, communities and the economy in Alberta.

Key ecosystem service management opportunities for Alberta lie first in building greater knowledge and understanding of ES, and the connections and dependencies between ES and wetlands and surrounding land use. Other opportunities include maintaining, restoring and/or enhancing the ES that people value and depend on to improve long-term human well-being, and support sustainable and successful development.

---

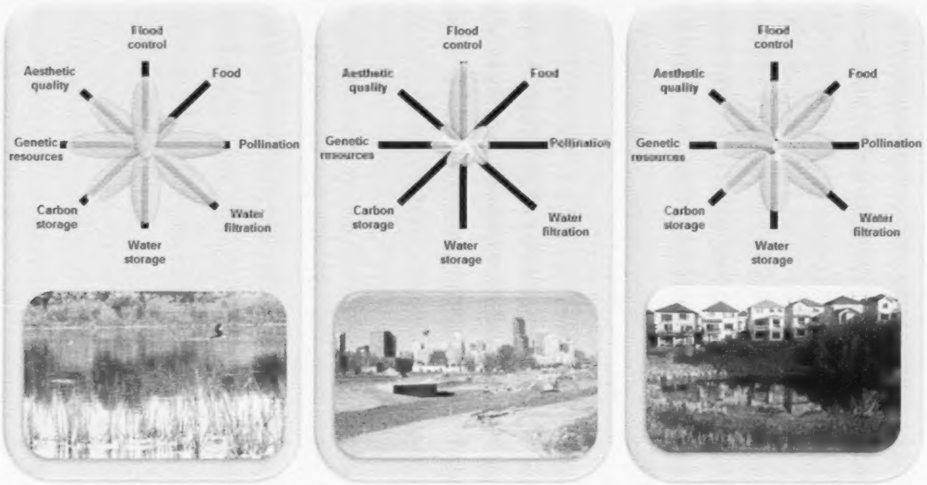
[3] This list is illustrative and does not represent the costs associated with wetland loss, alterations or degradation in the pilot's case study area

Development can encourage the maintenance or improvement of ES (e.g., avoidance of Environmentally Significant Areas, preserving adequate buffer zones around wetlands, etc.) providing opportunities for improving human well-being at the same time as increasing environmental sustainability. For example, building boardwalks around a wetland improves access to the wetland, increasing the potential for recreation, educational and aesthetic benefits, but may adversely impact other ES. Managing natural and constructed wetlands according to best ecological practices can maximize bundles of ES, such as flood control, water filtration and aesthetic and recreation values that are underpinned by high levels of biodiversity (MA, 2005) (see Text Box 2).

Text Box 2 - Bundles of ES produced by Wetlands

Natural wetlands produce 'bundles' of ecosystem services (ES), or in other words, many interrelated ES that benefit humans in a multitude of ways. Different 'bundles' of ES are obtained based on particular options and land-use choice pursued. The graphic below shows that when undisturbed wetland ecosystems are replaced by less diverse, engineered systems such as storm water retention ponds for residential development, the capacity of many services can be diminished. However, it is possible to manage for specific land development objectives such as subdivision development while minimizing losses of other ES; bundles of ES provide more benefits for a greater diversity of stakeholders.

Note: images provided are illustrative only.


Flood control
Aesthetic quality
Food
Genetic resources
Pollination
Carbon storage
Water filtration
Water storage
Flood control
Aesthetic quality
Food
Genetic resources
Pollination
Carbon storage
Water filtration
Water storage
Flood control
Aesthetic quality
Food
Genetic resources
Pollination
Carbon storage
Water filtration
Water storage

Images: Geneva Claesson (2011), City of Calgary (2010, Phil Bakes (2010)

1.2 Context of the ES Pilot

The ES pilot was launched to contribute to the ES road map, and build on the ES experience, information and knowledge developed through the regional planning initiatives conducted for southern Alberta in the past few years[4]. Regional planning has provided opportunities for the Government of Alberta to include the concept of ES into decision making.

At a strategic level for government, one of the key uses of the ES pilot is to contribute new tools and information to support Alberta's shift to Cumulative Effects Management (CEM) (see *Text Box* 3 below).

Text box 3 – Cumulative Effects and Cumulative Effects Management (CEM)

Within Alberta, Cumulative Effects Management has become an environmental management priority through the *Alberta Land Stewardship Act* and the business plan priorities of AENV and other departments.

Cumulative Effects is defined as "the combined effects of past, present and reasonably foreseeable land-use activities, over time, on the environment." (Land-use Framework, 2009). Sometimes this will occur over time, for example, when new development starts up in an area that already has environmental impacts from previous activities. Cumulative effects also occur when multiple activities take place across an area and lead to synergistic and sometimes rapid impacts on the environment. Wetland loss is a prime example of cumulative impact on ES as the issue is driven by the loss of many small basins which, cumulatively, equate to a large cumulative effect.

Cumulative effects *management* aims to set environmental objectives in consideration of their social, economic and environmental consequences and to manage activities, through a process of continuous improvement, in order to achieve those objectives. It is not an add-on to Alberta's current management system, but an evolution of that entire system.

The Ecosystem Services methodological approach can support cumulative effects management by providing:

- qualitative and quantitative methods to determine cultural and economic benefits derived from the environment in a place-based context;
- integrated information on the biophysical, economic and cultural dimensions of environmental resources to support trade-off discussions in decision making, policy and planning; and
- science and social-science-based evidence of society's benefits and dependence on ES for human well-being (e.g., clean water, fresh air, and food).

To provide the scope of the project, two early deliverables were produced: 1) a report on the current wetland approval process in southern Alberta; and 2) a case study report to select the geographic area. These two deliverables provide the ES pilot with focus; it was designed to inform a specified policy aspect - the current wetland approval process for residential subdivision development - in the selected case study area; however, the results and lessons learned can be used to inform broader provincial development.

---

[4] Regional planning for southern Alberta has involved two key initiatives: first, the Southern Alberta Landscapes (SAL) was launched in 2002 as a cross-Ministry, inter-governmental, strategic planning initiative to examine sustainable development issues in southern Alberta; and second, with the approval of the Alberta Land-use Framework, the South Saskatchewan Regional Plan was undertaken to develop outcomes for the region to help with planning and development goals while maintaining valued landscapes.

The various planning and policies regarding residential subdivision development are summarized here:

- Wetland management on private land in Alberta is guided by the Wetland Management in the Settled Areas of Alberta: An Interim Policy (1993);
- Applications for residential subdivision development that propose impacts to wetlands require provincial (under the *Water Act*) and municipal (under the *Municipal Government Act*) approvals[5];.
- Proponents submit a Wetland Impact Assessment (WIA) or a Biophysical Impact Assessment (BIA) to the required municipality detailing potential impacts any environmentally significant features for potential protection under other regulatory requirements (e.g., *Species at Risk Act*);
- If the municipality approves the application, proponents apply to AEW under the *Water Act*[6]; and
- Wetland approval writers at AEW review the application (limited to the aquatic environment and hydrology), and apply the Provincial Wetland Restoration and Compensation Guide to determine how the mitigation hierarchy[7] will be applied, including compensation requirements.

The current process and various requirements of development proponents do not incorporate information about ES functions, benefits or value to local beneficiaries. This was identified as an opportunity to pilot an ES approach to enhance decision making. While the description above is the current process, the Government of Alberta is working on a new wetland policy and it is expected that some of the ES pilot work will inform the development of this new policy.

Through research and engagement it became apparent that, currently, there were two key areas of improvement in the regulatory process above that could benefit from ES information:

- Many benefits that wetlands provide to humans are not accounted for in the wetland approval process for residential sub-division development. While residential developers may consider the flood control benefits of wetlands, other benefits like carbon storage and habitat for pollinators are omitted. In addition, development applications are reviewed individually. The result is development approval decisions made without understanding of individual and cumulative ES benefits that are being improved, degraded or lost as a result of residential development; and

---

[5] Each municipality has its own requirements for wetland approvals prior to submission to AENV wetland approval writers. The ES Pilot only focused on the process relevant for the City of Calgary and the MD of Rocky View.

[6] If the wetland is on public land, the development application will require authorization under the *Public Lands Act*. For the purposes of the ES Pilot, the *Public Lands Act* was not considered.

[7] The Mitigation hierarchy describes the approval decision process of avoidance, minimization or compensation when assessing an application that will impact a wetland.

- While guidelines, protocols and the *Alberta Water Act* allow for discretion in making decisions about wetland mitigation (i.e., avoidance, minimization and compensation by development proponents), there is a perceived culture of developers requesting compensation options rather than investing in alternative development options. Wetland approval writers require more information to better equip them to ensure the application of the mitigation hierarchy maintains local assets and ES.

Building upon the above areas of improvement, the wetland approvals decision makers helped the ES pilot team to identify, frame and prioritize key gaps in the wetlands approval process to which the pilot was to focus its assessment work. The following represent the refined gaps that were used to design the project:

1. **There is insufficient evidence to support avoidance, minimization and compensation decisions on wetlands.**
2. **There is insufficient consideration of cumulative effects and long-term consequences of decision making. There is limited ability to communicate the 'values' of wetlands.**

Based upon the steps of an ES approach designed for the purposes of this pilot project (*Figure* 1), and in order to establish what information was required to address the three gaps, the pilot team developed questions to guide the assessment activities (Text Box 4).

Text Box 4 – ES Approach questions addressed in this report

- What ecosystem services are produced by wetlands in the case study area?
- What benefits accrue to local and regional people from wetland ecosystem services?
- What trends can be observed about the condition of wetland ecosystem services over the past several decades?
- What characteristics of wetlands are critical for function and service delivery? (e.g., proximity to other wetlands, adequate riparian buffers, etc.)
- What are the potential impacts to the entire case study area resulting from the cumulative draining of wetlands for residential subdivision development?
- Where are the 'priority' (i.e., high function and high value score) wetlands identified through site-specific assessment?
- What questions and/or additional information can the wetland approval writers inquire from development proponents to understand the potential losses and benefits to ES resulting from the subdivision development?
- What data, capacity and information gaps were identified?

1.3 An ES Approach for Alberta

A key objective of the ES pilot (see Section 1.1) was to test and demonstrate how to operationalize an ES approach for Alberta based on existing research and available methods from other organizations and jurisdictions. The ES approach developed for the Alberta context (*Figure* 1) provides a framework to help identify and quantify - qualitatively, quantitatively and monetarily - the benefits provided by wetland ecosystems, with the goal of improving decision making. As improvements are made in describing and valuing the benefits of ES, decision makers can better understand how their decisions might change (positively or negatively) the condition, quality and/or quantity of ES that could impact the well-being and quality of life of Albertans, and the businesses that operate in the province.

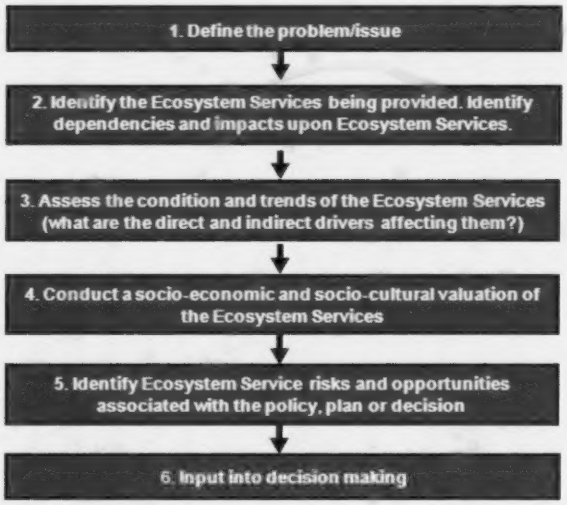

1. Define the problem/issue
2. Identify the Ecosystem Services being provided. Identify dependencies and impacts upon Ecosystem Services.
3. Assess the condition and trends of the Ecosystem Services (what are the direct and indirect drivers affecting them?)
4. Conduct a socio-economic and socio-cultural valuation of the Ecosystem Services
5. Identify Ecosystem Service risks and opportunities associated with the policy, plan or decision
6. Input into decision making

Figure 1: Ecosystem Services Pilot - ES Approach

Based upon the most current and renowned expertise at the time, the ES pilot attempted to follow process guidelines provided in two ecosystem service references: Ecosystem Services and Human Well-Being: a manual for assessment practitioners (Ash *et al.*, 2010) and Ecosystem Services: a guide for decision makers (WRI, 2008). These references provide individuals and organizations with information on how to conduct ES assessments, and ensure the consideration of "both the ecosystem from which the services are derived and also the people who depend on and are affected by changes in the supply of services" are integrated (Ash *et al.*, 2010). Alberta's experience in ES work was further drawn upon to develop methods for use in the pilot including results from the Southern Alberta Landscapes project and the South Saskatchewan Regional Plan process (Kerr, 2010).

Emphasis was placed on **developing processes and products considered to be scientifically credible, relevant to key decision makers and legitimate in the eyes of stakeholders**. A Steering Committee was established to ensure project outcomes and objectives were accomplished, and to provide guidance and oversight to the process and deliverables. Using a consensus-based approach, the Steering Committee was composed of target decision makers and other stakeholders representing government, industry, non-profit and academic communities. In addition, a Review Panel was established to contribute to the delivery of the ES approach, provide contextual information about Alberta and ES and enhance project credibility by reviewing deliverables.

Information was developed from a variety of different data sources (e.g., satellite imagery, government databases, experiential knowledge, internet sources, etc.), as well as from reports and peer-reviewed scientific literature. The pilot involved multiple scales: both site-level and remote assessments undertaken at the scale of the whole study area. The pilot attempted to create uniformity across data applied but recognize that there were inconsistencies and gaps in the data available. As such, limitations to the assessment results are noted and additional questions identified throughout the process are highlighted.

2.0 Understanding the Context for a Place-based ES Assessment: Results of Research on the Case Study Area, Drivers of Change and Stakeholder priorities

2.1 Description of the Case Study Area

The case study area covers approximately 274 square kilometres, encompassing parts of the City of Calgary and Rocky View County and the Town of Chestermere (*Figure* 2). This area was chosen for the ES pilot because of the large number of wetlands in the area, current pressure from residential sub-division development and the existence of data to support spatial analysis of ES. The study area is primarily agricultural (~57 per cent), with increasing settled areas (~17 per cent) and industrial areas (~10 per cent).

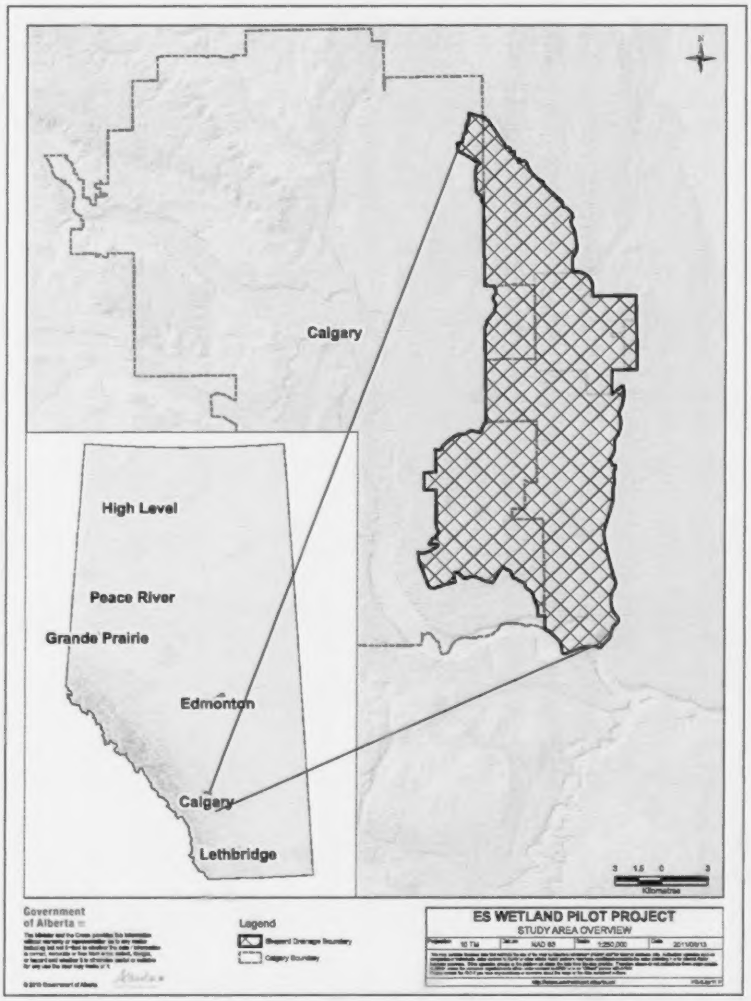

Calgary
High Level
Peace River
Grande Prairie
Edmonton
Calgary
Lethbridge
3 1.5 0 3
Kilometres
Government of Alberta
Legend
Calgary Boundary
ES WETLAND PILOT PROJECT
STUDY AREA OVERVIEW
10 TM
NAD 83
1:250,000
2011/09/13
© 2010 Government of Alberta

Figure 2: Case study area - wetland ecosystems in Rocky View County and East Calgary

Text Box 5 - Wetland Classification Systems

Wetlands can vary greatly and classification systems that compare wetlands using standard sets of metrics help communicate the characteristics of individual wetlands. This information is important for understanding regional wetland ecology and for developing approaches to wetland management. For example, decision-makers may be interested in learning whether different classes of wetlands provide different ecosystem services, and whether decisions regarding different classes of wetlands can be made based on an understanding of what ES are provided by each class. Currently, the province of Alberta uses two main wetland classification systems: the Steward and Kantrud (S&K) System and the Canadian Wetland Classification System.

The **Steward and Kantrud Classification** (S&K) system is used to classify wetlands in the glaciated prairie region (including the ES Pilot case study area). Stewart and Kantrud found that the use of prairie ponds and lakes by waterfowl is strongly influenced by water permanence, depth, chemistry and land use.

The **Canadian Wetland Classification System** is based on a hierarchal system, which includes the class of the wetland, wetland form and wetland type. The five wetland classes are differentiated by their development characteristics and the environment in which they exist. The five classes are: bog, fen, marsh, swamp, and shallow water. Wetlands that accumulate peat (partially-decomposed organic matter) are called peatlands. The Canadian Wetland Classification is used across Canada, which allows for comparison with most other wetlands, but is a less precise classification approach.

AEW is currently developing a provincial wetland classification system to provide consistent assessment across the province. This will be helpful for future ES assessments to ensure comparability between wetlands.

The case study area is characterized by cultivated plains, and slopes from the northwest to the northeast resulting in drainage towards the Bow River at the south end of the boundary (AECOM, 2011). In its natural condition, most of the area is a "non-contributing area" or a basin with no surface outlet to the Bow River. The low-lying topography of the areas leads to the accumulation of water during the wet season and the creation of wetlands over time (AECOM, 2011).

According to 2005 data, there are over 6,400 wetlands in the case study area, ranging in size from less than 0.1 hectare to over 10 hectares. Approximately 11 per cent, or 24.5 square kilometres, of the landscape is covered by many clusters of wetlands and Class I though VI wetlands, based on the Stewart and Kantrud (S&K) classification system. A key limitation identified by the pilot is the lack of a complete wetland inventory for the entire case study area. The largest wetlands are found in the Shepard Slough Complex, located in the southern end of the study area.

While the number of wetlands has increased since 18 per cent since 1962[8] (~5293 wetlands Class 1 - VI), wetland coverage has been reduced by 24 per cent (*Figure* 3). This translates into a **total loss of 7.7 square kilometres of wetlands** between 1962 and 2005. There are a number of reasons why the area saw an increase in the number of wetlands, including mapping during different seasonal conditions, the use of different techniques and the ability to conduct field verification in the recent estimate, which was unavailable in the historical dataset.

---

[8] Historic dates for wetland information is inconsistent throughout the report. A key data source was a wetland inventory prepared using multiple years of data from the early 1960's. Consultants preparing reports used different temporal points for their assessments, however there are no implications for the results data.

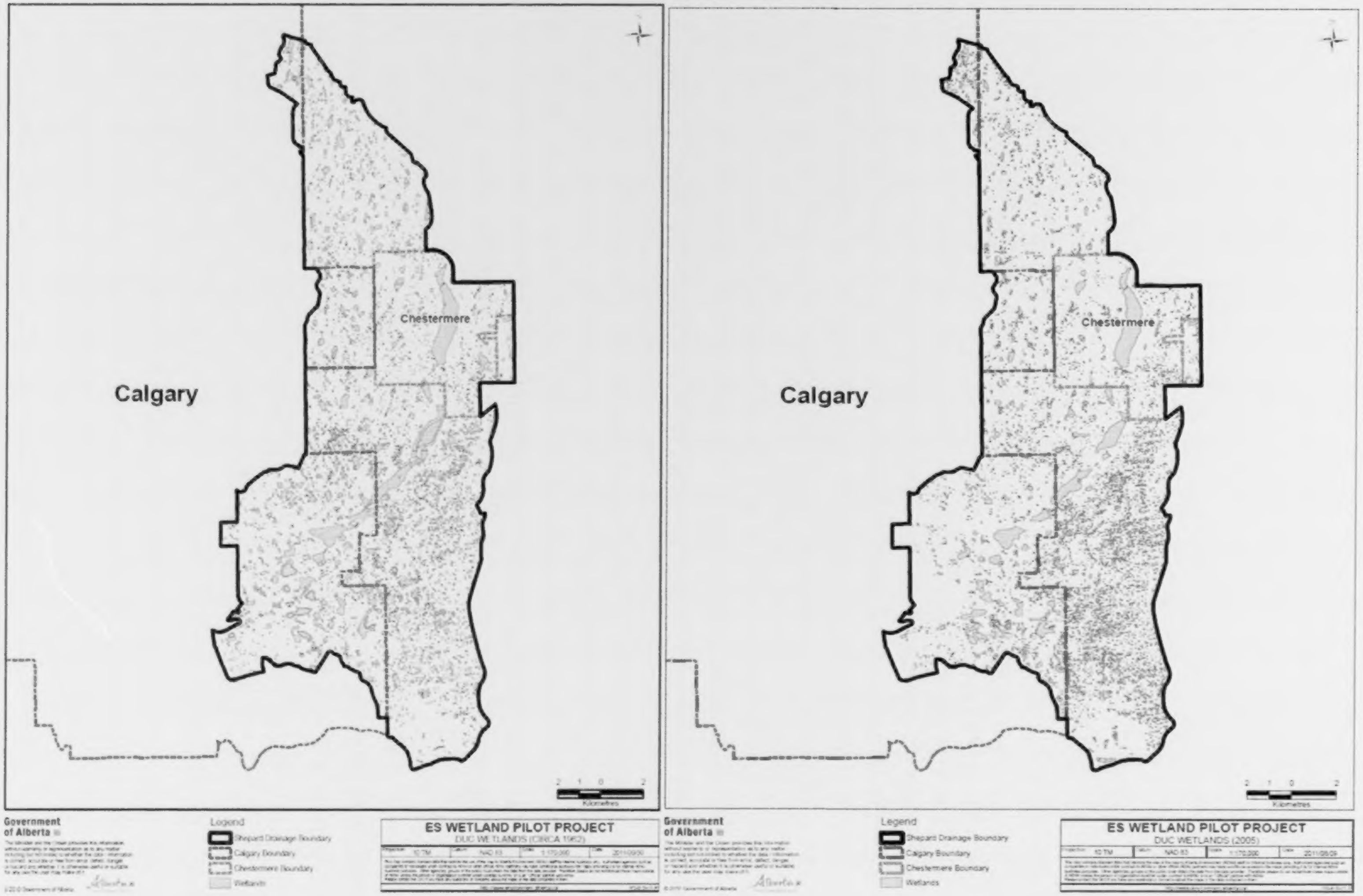

Calgary
Chestermere
2 1 0 2
Kilometres
Government of Alberta
Legend
Shepard Drainage Boundary
Calgary Boundary
Chestermere Boundary
Wetlands
ES WETLAND PILOT PROJECT
DUC WETLANDS (CIRCA 1962)
10TM
NAD 83
1:170,000
Calgary
Chestermere
2 1 0 2
Kilometres
Government of Alberta
Legend
Shepard Drainage Boundary
Calgary Boundary
Chestermere Boundary
Wetlands
ES WETLAND PILOT PROJECT
DUC WETLANDS (2005)
10TM
NAD 83
1:170,000

Figure 3: Change in wetlands from 1962 - 2005

2.2 What is Driving Change in Wetlands in Rocky View County and East Calgary?

The ES pilot study area is nested within the South Saskatchewan Region. Historic landscape change in this region has been primarily driven by population growth and agricultural expansion (SSRP Profile, 2009). For example, according to research in South Saskatchewan Region Planning (SSRP) documents, over a million hectares of prairie-parkland wetlands were drained and converted to agricultural use in the past century. In addition, between 1970 and 1990, approximately 2.4 wetland basins per square kilometer were lost in the region for agricultural land use (SSRP Profile, 2009).

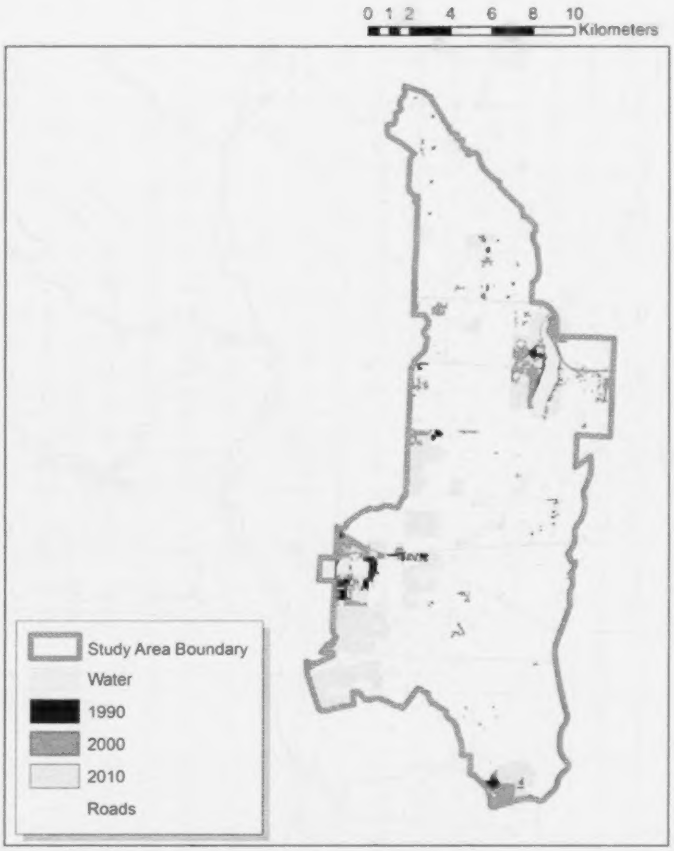


Figure 4: Change in urban land use in case study area

Wetland margins, which provide even richer wildlife habitat than the wetlands themselves, have shrank or disappeared in the South Saskatchewan Region. This typically results in a loss of wildlife habitat and can produce detrimental effects on water and soil quality. It can also lead to changes in hydrological systems. Wetland removal, tile drainage, irrigation and drainage canals, engineered inlets and outlets to wetlands and alteration of wetlands have also resulted in changes to the hydrological system in the region (SSRP Profile, 2009).

More recently, urban expansion has led to new changes on the landscape, including increased percentage of impervious surfaces, stormwater pond creation and new micro-climactic conditions (*Figure* 4)[9]. Population growth, particularly in the Calgary area, has led to expanded development in the area. Rural and agricultural lands are increasingly under pressure from rural residential development, while tracts of agricultural land have been converted to facilitate the geographic expansion of Calgary. The conversion of native landscapes over time has affected biodiversity in the SSRP; it is now home to the largest number of species at risk in Alberta (e.g., Piping Plovers in the sub-basin) (SSRP Profile, 2009). The Calgary region has experienced significant economic and population growth over the past decade, and that growth has extended eastward into Rocky View County. With a population of more than one million people, the city of Calgary is the fourth largest city in Canada. Its population has grown rapidly over the past decade, by approximately 20,000 persons per year on average. Residents are attracted to opportunities created by the city's diverse economic base and the province's strong GDP growth (estimated at 3.9 per cent in 2012) which has been fuelled by a thriving energy sector (CED, 2010; RBC, 2011).

---

[9] The land use changes in the map below include agriculture (cropland, grasslands and pastures) and urban land use (roads, buildings and pavement).

The majority of Rocky View County's population growth has derived from net in-migration to the municipality rather than natural growth, and more than two-thirds of Rocky View's adults are employed outside of the municipality. The County's population over the period 1971 to 2006 grew from 10,400 to almost 34,200, an annualized growth rate of 3.5 per cent.

Accompanied with population growth is the increased pressure for residential development. The fastest growing residential development type in the South Saskatchewan Region is rural residential development. Given its low dwelling density, this type of residential development exerts a large footprint on the land base. Rural residential development occurs predominantly along the Highway 2 corridor and around urban centers. Between 2000 and 2006, 87 per cent of the municipality's population increase occurred outside of the designated hamlets, and within acreage subdivisions. The most growth occurred between 1980 and 2002, especially around the margins of Calgary, in areas including Rocky View County (SSRP Profile, 2009).

The expansion of human settlement, particularly the establishment of structures, such as housing and roads, impacts wildlife movement corridors and increases the interaction between wildlife and humans. Rural residential development can also result in the spread of invasive weeds, increase air and water pollution and cause landscape alterations that impede natural ecological processes such as water flow and fire. With increased settlement, the demands for tourism, recreation and amenity resources will also continue to increase, as will demands for natural resource development.

The trend of urbanization in the South Saskatchewan Region shows no signs of abating, as Alberta's economy continues to attract new residents from other parts of Canada and internationally. It is estimated that the region's population will expand by two million people by 2076; of this total, 1.6 million are expected to settle in the Calgary metropolitan area (City of Calgary, 2011). Consequently, urban areas may be under pressure to further expand in order to accommodate larger populations and approve associated residential and commercial development which could produce increasing pressures on the current wetland inventory in the region.

2.3 Wetland Ecosystem Services in the Case Study Area

Despite continuing losses of wetlands in this region of Alberta, there is a growing recognition that wetlands provide a range of ES that are beneficial to society. This contribution has been recognized by local municipalities either as explicit policy objectives or as part of land-use planning processes. For example, the City of Calgary developed a Wetland Conservation Plan that explicitly recognized wetlands as providers of water quality and supply, flood attenuation, erosion control and a variety of socio-cultural benefits (Calgary Conservation Plan, 2004).

An **early finding of the ES pilot** was that ecosystem service benefits are context specific, as they relate as much to how the environment is used and valued as to how services are produced by ecological processes. Therefore, it is recognized that the study site and results derived from the assessment are not representative of all wetlands or wetland types in Alberta or elsewhere.

The ES pilot conducted a workshop and consulted with decision makers, local people that benefit from ES and other stakeholders in order to identify ES that are important in the study area. There are numerous ES to assess, and the pilot conducted activities to narrow the focus allows for the identification and assessment of context-specific ES, as well as information that resonates with local people and groups. For example, water storage was identified as an important ES, however the production of genetic materials was not and as such it was not assessed.

Table 1 presents the ES identified as important for the pilot study to focus on, along with a list of people or groups that benefit from the services identified by workshop participants and other advisors to the pilot.

Table 1. List of ES, definitions, and examples of beneficiaries

Ecosystem Service	ES Pilot Definition	Beneficiary Group in the Case Study Area	Sub-Group
Water supply and storage	Storage and retention of water in wetlands for domestic, industrial and municipal water use	Agriculture	Livestock, Crops
		Residential dwellings	Home owners, Developers, Municipalities
Carbon storage	The stock of organic carbon stored in soils for Class 3, 4 and 5 wetlands. *Note: Class 1 and 2 were not included due to methodology limitation.*	Albertans	Not applicable
Flood control	The timing and magnitude of runoff and flooding can be strongly influenced by changes in wetlands	Residential dwellings	Home owners, Developers, Municipalities
Water filtration/ purification	Role ecosystems play in the filtration and decomposition of organic wastes and pollutants in water; assimilation and detoxification of compounds through soil and subsoil.	Agriculture	Livestock, Crops
		Municipalities/ Government	Rocky View County, Calgary, Alberta government
		residential	Municipalities, Home owners, Citizens
Pollination	The fertilization of floral plants	Agriculture	Farmers, Buyers/ Grocery stores
Soil Formation	Process by which organic material is decomposed to form soil.	Agriculture	Farmers
		residential	Municipalities, Home Owners, Citizens
Recreation and tourism	Providing opportunities for recreational activities. Including: eco-tourism, sport fishing and other outdoor activities	Recreation Groups	Birders/ Botanists/ Hiking
		Tourism	Local/ Provincial/ Other

Ecosystem Services	ES Pilot Definition	Beneficiary Group in the Case Study Area	Sub-Group
Heritage	The value that individuals place on knowing that a resource exists, even if they never use that resource	First Nations	First Nation groups
		Settlers, Citizens	Historic associations/ societies, Sense of place
Science and educational value	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies	Education Groups	Schools/ Government Outreach/ ENGO Outreach
		Science	Schools/ universities/ Research groups
Food/ crops	That portion of gross primary production extractable as food for human and/or cattle production	Agriculture	Farmers
		Public	Buyers/ Grocery stores
Aesthetic	Beauty and enjoyment provided by landscapes with wetlands	Citizens	Local, Recreation and Tourism groups
Erosion control	Retention of soil within an ecosystem. Role ecosystems play in retaining and replenishing soils.	Residential	Home owners, Developers, Municipalities

There are a number of beneficiaries of the ES that are produced by wetlands in the case study area. Beneficiaries can occur at different scales. For instance, residential home owners benefit at the local scale from flood control of a wetland or small wetland complex[10]; however flood control produced by wetlands across the entire case study area can have benefits outside the area to stakeholders such as the City of Calgary and Rocky View County that have to manage flooding within their jurisdictions, or to communities further downstream. In addition, benefits accrue to the provincial government in terms of reduced flood mitigation and compensation costs when flood control is provided free by wetlands.

Through a series of working sessions, the ES pilot's 'decision makers' (i.e., wetland approval writers) chose three ES as being the top priority for greater understanding: **water storage/supply, flood control** and **water purification/quality**. These three ES were chosen for in-depth assessment along with **carbon storage**, which was included as it is an important part of the provincial Climate Change Strategy and related regulations. Other ES (e.g., pollination) were described and investigated in terms of their contributions to local society, but their condition (e.g., quality, quantity and distribution) was not assessed in detail across the entire study area.

A broader selection of stakeholders, including ES beneficiaries, **identified cultural ES as high priorities for management** in survey responses and workshop discussions. A specific goal of one workshop with stakeholders was to understand perspectives on cultural ES, which are challenging to assess. Stakeholders were asked to rank the twelve ES included in the ES pilot in terms of their importance to individual stakeholders, of their importance to the stakeholder group that each individual represented, and of their perceived importance to society as a whole (*Table 2*).

---

[10] A wetland complex refers to two or more separated wetlands related by biological or hydrological functions. Using satellite-based radar images permits the identification of wetland complexes based on hydrological connections, however, wetland complexes are more commonly identified using distance thresholds (e.g., wetlands within a 50-meter buffer could be considered a wetland complex).

Table 2: Rank order of benefits from ES organized by their perceived importance to the individuals, their stakeholder group, and to society. One is the highest ranking and twelve is the lowest ranking.

	Individuals	Stakeholder Group	Society
Water filtration/purification	1	3	1
Aesthetic (beauty and enjoyment)	2	6	8
Water quantity regulation	3	1	1
Flood control	4	2	3
Science and Educational Value	5	8	10
Recreation and tourism	6	5	5
Erosion control	7	4	4
Pollination	8	11	5
Food Crops	9	7	10
Soil formation	10	10	7
Carbon storage	11	12	8
Traditional Use	12	9	12

The results from the stakeholder dialogue confirmed assumptions about the perceived value of some ES, such as flood control and water purification, that are highly important across the three categories. The results also show that a number of the less obvious or harder to measure ES such as aesthetic and recreational benefits are important across the three groups as well. Biodiversity was also considered to be highly important to most stakeholders, however biodiversity is considered to be a necessary condition for the provision of ES, but not an ES itself (see Text Box 5).

Text Box 5 - Is Biodiversity an Ecosystem Service?

An ES Approach used an "utilitarian" concept of nature, in which biodiversity is understood to be a necessary condition for the production of ecosystem services, but not an ecosystem service itself (Ash *et al.*, 2010). Biodiversity underpins the supply of ES such as seed dispersal, pollination, pest and disease control, and carbon storage. Therefore, changes in biodiversity will affect the quality and quantity of ES available to humans. In addition, the intrinsic value some people place on biodiversity can be captured under the cultural ecosystem service called "ethical values".

Within Alberta, the Department of Sustainable Resource Development (SRD) manages biodiversity for the province. SRD has been leading the development of a draft Biodiversity Strategy. Once this strategy is released there will be opportunity to further define the relationship between ES and biodiversity for the Government of Alberta.

3.0 Ecosystem Service Assessment Results

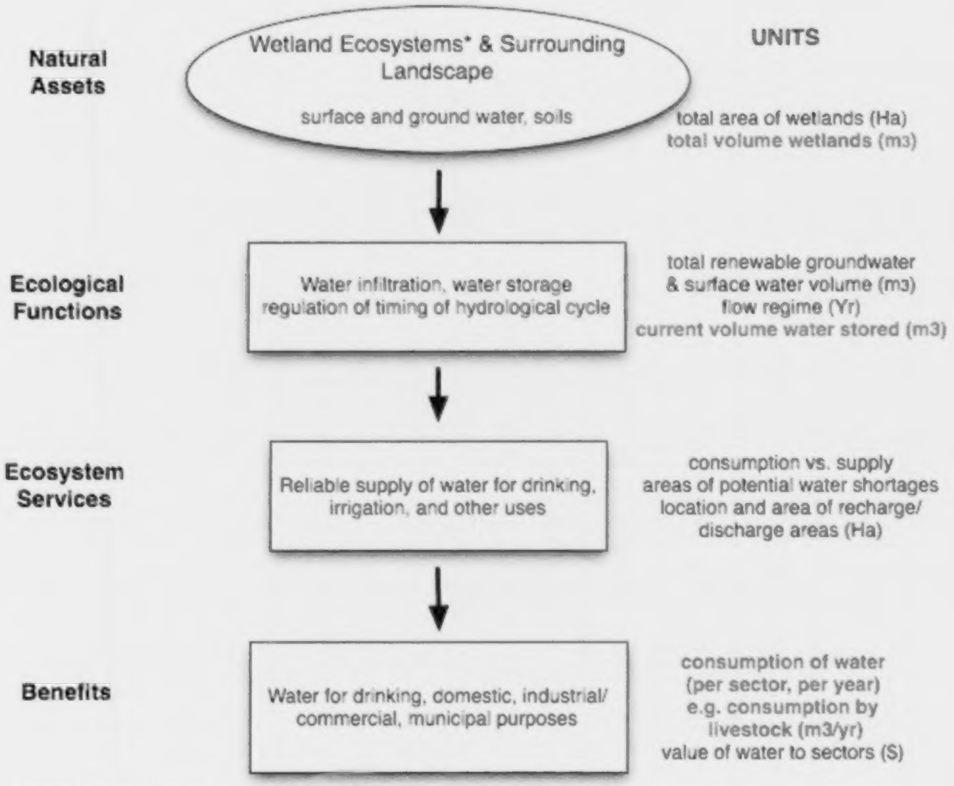
In order to better understand and communicate the complex concept that is 'ecosystem services', the ES pilot developed a conceptual map of the relationship between ecosystem assets (e.g., wetlands), ecological functions, services and benefits (see Roy Haines-Young and Marion Potschin (2010) for more information on the 'ecosystem cascades' concept). Using the example of ***water storage and supply***, *Figure 5* shows how natural assets lead to ES and provides examples of the specific benefits that people obtain from this service. Wetlands are assets on a landscape, and incorporate many ecological functions, such as water infiltration and regulation of hydrological cycles and micro-climates. A resulting ES is water storage, and people might benefit from this service by having a reliable source of water for drinking or watering livestock, by swimming or recreating in water bodies downstream from the wetland, by living close to a beautiful wetland and appreciating the aquatic species that the wetland supports.

An ES 'cascade' diagram was developed for each ES in order to identify indicators to be used in their assessment. Because data was not available to assess every component of the system (a common experience in ES assessment work according to experts), ES were assessed using one or several indicators that might represent the asset, the function, the service or benefits. In a more comprehensive ES assessment, the more indicators that can be used to understand the entire ES cascade across time and space, the more informative the results will be to decision makers. In addition, the beneficiaries and benefits for each ES are ideally identified and quantified in order to understand who relies on which ES and thus how decisions affecting ES will affect people. Due to the limitations of undertaking a pilot project, this report gathered partial information on the ES cascades and on the beneficiaries of each ES. We hope that these results will provide information that will be useful to decision makers and also present ideas for the types of information that can be developed from the ES perspective. For each ES, we identify questions that we could not answer due to project limitations that could provide important insight into wetland management in the study area.

The first four ES presented in this section – **water supply/storage, flood control, water quality and carbon storage** – were assessed for the ES pilot at the scale of the entire study area. Project constraints required collaboration with three consultant teams to conduct the assessments. This allowed for experimentation with a range of approaches, however, comparability between each ES was then limited[11]. For each of the four ES, we provide a description of the ES, brief assessment methods, the condition and historical trends of the ES, the relationship between the ES and human well-being, and outstanding questions for further exploration. Full methods for the assessment of these four ES are provided in separate technical reports written by consultant teams. Additional ES produced by wetlands in the study area were assessed using available information that was less representative of the entire study area. They include food/crops, pollination, erosion control and soil formation, and several cultural ES.

---

[11] Similar datasets were used by all consultant teams, however, because their methods and needs differed and there was not enough time within the pilot to integrate their findings, results are reported for slightly different time periods (e.g., 1962 for carbon sequestration vs. 1965 for water storage and flood control), and similar types of results differ slightly across ES (e.g., percentage loss of wetlands across time).


Natural Assets
Wetland Ecosystems* & Surrounding Landscape
surface and ground water, soils
UNITS
total area of wetlands (Ha)
total volume wetlands (m3)
Ecological Functions
Water infiltration, water storage regulation of timing of hydrological cycle
total renewable groundwater & surface water volume (m3)
flow regime (Yr)
current volume water stored (m3)
Ecosystem Services
Reliable supply of water for drinking, irrigation, and other uses
consumption vs. supply
areas of potential water shortages
location and area of recharge/ discharge areas (Ha)
Benefits
Water for drinking, domestic, industrial/ commercial, municipal purposes
consumption of water (per sector, per year)
e.g. consumption by livestock (m3/yr)
value of water to sectors ($)

*Wetland ecosystems include biodiversity, water, soils, above and below-ground biomass, landscape features

Figure 5. Ecosystem Services Cascade showing Natural Assets, Ecological Functions, Ecosystem Services and Benefits related to Water Storage and Supply. Examples of indicators are listed on right of diagram (not a complete list). The ES Pilot assessed indicators highlighted in red.

In addition to the ES selected for the ES pilot, 21 wetland sites were assessed individually, using an ES rapid assessment tool called WESPUS[12]. The results of these site assessments, conducted both to test the tool and to assess a sample of different types of wetlands at the local scale, are presented at the end of this section.

---

[12] The Wetland Ecosystem Services Protocol for the United States (WESPUS) is a rapid assessment tool developed to evaluate the function and value of wetland ecosystem services (Adamus, 2011).

3.1 ES: Water Supply/Storage

3.1.1 Description of water supply/storage ES

Freshwater supply is of primary importance to people around the world for drinking water, domestic, agricultural and industrial use, for recreation, and to support other ES that require reliable supplies of water for their existence. Global freshwater use expanded by an estimated 10 per cent from 2000 to 2010, reflecting population growth, economic development and changes in water-use efficiency. This trend is projected to continue, leading to water shortages in many parts of the world. Water supply is an issue of concern in Southern Alberta because of rapid population and economic growth, uncertain effects of climate change, a continuing decline in water quality, high per capita use of water and a finite supply of water from the Bow and Elbow Rivers (City of Calgary, 2007). In the study area, all water licenses have been allocated and new development must secure water licenses that are pre-existing (Alberta Environment, 2006). Future development may be constrained by water supply, which has led the City of Calgary to promote a variety of approaches to increase water-use efficiency and the conservation of water resources on the landscape.

Water storage in wetlands is influenced by the number of wetlands on the landscape, the types of wetlands and the connectivity within wetland complexes. Therefore, the removal of one wetland may have impacts to water storage at the scale of the wetland complex or landscape. Wetlands can also be connected to surface waters that are the primary supplies of water for human consumption and may be important for groundwater recharge. In the study area, water stored in wetlands has the potential to be used directly or indirectly as an input into agriculture for crops or livestock watering, industrial source water, recreational pursuits or other purposes that benefit people. While most of the wetlands in the study area are not connected to groundwater due to a shale and clay soil barrier (Domestic Water Well Assessment, 2007), there are a few areas where groundwater recharge occurs, although it is not known whether there are domestic wells in these areas (AECOM, 2011). The amount of water stored in wetlands, and what this water contributes to human well-being, are important questions for landscape managers and not well understood in the study area.

Water storage in wetlands is crucially important for the production of other wetland ES and is interrelated to a number of wetlands services. With no water storage, there is no wetland, and diminished stores of water can lead to rapid losses of other wetland ES. Water storage guarantees sufficient moisture for the development of wetland soils and vegetation, which in turn supports many other wetland ES (Gilbert *et al.*, 2006; Mitsch and Gosselink, 2000). The storage of water is also strongly linked to the service of flood mitigation.

3.1.2 Method of assessment of water supply/storage

All wetlands in the study area were assessed for water storage functions. Two steps were used to determine total water storage capacity of each wetland:

1. existing water volume in wetland was calculated using the equation Volume(cubic metres)= 2850 X Area$^{1.22}$ (Manitoba Conservation *et al.*, 2000); and

2. additional wetland water storage capacity was calculated (i.e., the total capacity of the wetland when full using the mean elevation of the boundary of the wetland and subtracting the maximum water level).

The water storage capacities of individual wetlands were calculated by applying one metre (1m) grid LiDAR data in combination with a rating curve. The LiDAR data set was acquired during very dry periods in late fall (between 2007 and 2009), which results in a **conservative estimate of water storage capacity**.

A landcover dataset was created for the ES pilot using data from Ducks Unlimited Canada (DUC), the Calgary-Rocky View County Intermunicipal Development Plan (IDP) and Geobase land cover classification, all from a period between 2005 and 2008. Watersheds were delineated using LiDAR and WHITEBOX™ remote sensing methods in addition to previous delineations (e.g., City of Calgary's 'storm subcatchments').

The relationship between water supply/storage and human well-being was investigated in terms of the following:

- water uses identified in the case study area (e.g., watering of livestock);
- the relationship between this ES and other ES as identified in scientific literature; and
- the potential relationships between this ES and benefits for people in the area as identified in literature and reports.

Further questions that would be useful to answer in order to better understand how this ES contributes to the economy and well-being of people in the study area are presented in section 3.1.5.

3.1.3 Condition and trends of water supply/storage

The total water storage capacity of all wetlands in the study area was estimated to be **36.3 million cubic metres**. This represents a volume of water greater than the combined total storage capacity of the Glenmore Reservoir and Lake Chestermere. Water storage capacities of individual wetlands are shown in *Figure 6*. Much of the total water storage service capacity of wetlands is only realized in the spring, as water storage drops considerably over the summer as well as during dry years. Water storage capacity is strongly linked to flood control services (see Section 3.2), as wetlands hold high levels of water in the spring that would otherwise flood the landscape. In the fall of 2007 and 2009, when the LiDAR data using for assessing water storage was collected, seasonal and dry annual conditions resulted in an estimated total wetland volume of **14.3 million cubic metres** or **39.4 per cent** of total water storage capacity.

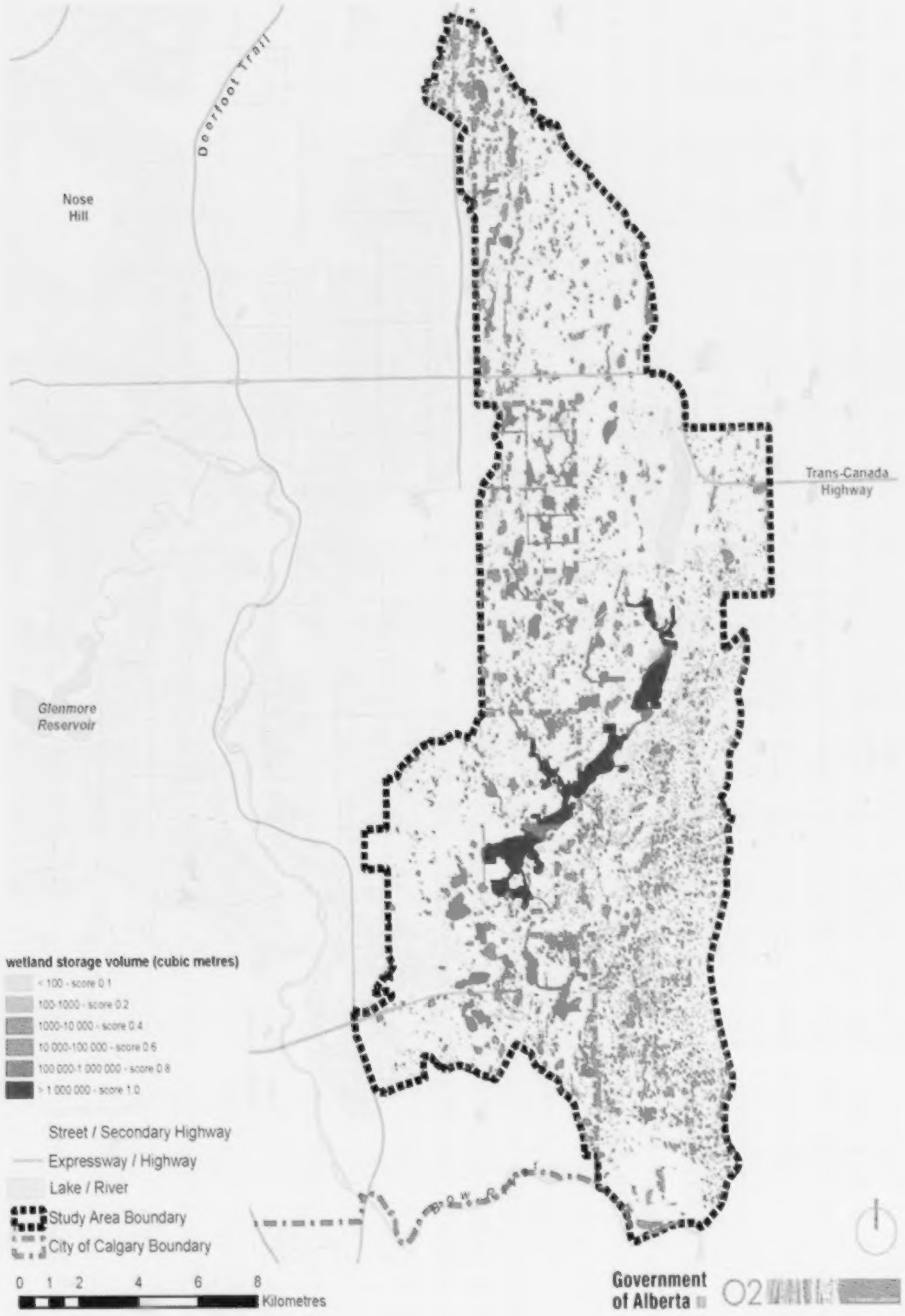

Deerfoot Trail
Nose Hill
Glenmore Reservoir
Trans-Canada Highway
Bow River
wetland storage volume (cubic metres)
< 100 - score 0.1
100-1000 - score 0.2
1000-10 000 - score 0.4
10 000-100 000 - score 0.6
100 000-1 000 000 - score 0.8
> 1 000 000 - score 1.0
Street / Secondary Highway
Expressway / Highway
Lake / River
Study Area Boundary
City of Calgary Boundary
0 1 2 4 6 8
Kilometres
Government of Alberta
O2

Figure 6. Volume of water currently held in individual wetlands.

Water storage capacities of wetlands were also analyzed according to wetland sizes and the S&K classification. *Table 3* shows that most water storage in the study area occurs in a few very large (>10 hectares) wetlands. Although the vast majority of wetlands in the study area are very small (<0.1 hectares), total storage capacity of this size class is only 3.2 per cent of the total amount. Wetlands between 0.1 and 1.0 hectares account for over eight per cent of the total, which is higher than the combined total of all wetlands between two and five hectares, and is almost as high as the total of those wetlands between five and 10 hectares.

From a cumulative effects management (CEM) perspective, small wetlands in the case study area perform an important water storage service when viewed together as a whole, and likely are very important to the hydrology and provision of wetland ES in the study area. However, it remains to be determined exactly how these small wetlands benefit people in the area and how important they are to the maintenance of hydrological regimes on the landscape. Similarly, an analysis of water storage capacity by S&K wetland class showed that because there are such a large number of wetlands that are Class I or II, their contribution to water storage on the landscape is substantial, even if individually they hold less water.

Table 3. Water storage capacity by wetland size class

Variable	Wetland Area Class Intervals (hectares)						
	<0.1 ha	0.1 – 1 ha	1 – 2 ha	2 – 3 ha	3 – 5 ha	5 – 10 ha	>10 ha
Total number in study area (n)	4647	1520	200	75	45	45	43
Mean volume (m^3)	248	1944	9010	17,776	31,490	68,476	571,849
Standard deviation of volume (m^3)	221	1393	5336	6726	11,266	31,024	1,223,217
Total volume in study area within size class (thousands m^3)	1151	2956	1802	1333	1417	3081	24,590
% of total study area volume	3.2%	8.1%	5.0%	3.7%	3.9%	8.5%	68%

Water storage capacity in wetlands was found to have **decreased since 1965** due to wetland drainage. This change was calculated using a drained wetland inventory assembled by DUC, which attempts to control results for climate variability. Water storage capacity in 1965 was calculated as 45.5 million cubic metres. The estimated **total storage capacity lost due to wetland drainage between 1965 and the present is 9.2 million cubic metres**. This represents a **20 per cent decrease** in available water storage capacity in the study area. With continued development as a goal for both Rocky View County and Calgary, a continued decreasing trend can be predicted if planning and approval decisions remain unchanged. *Figure 7* presents where wetlands have been lost across the study area due to wetland drainage.

Losses in wetland water storage during this period were concentrated in the central part of case study area, although major changes were also observed on the western margins of the study area, where new City of Calgary subdivisions have been built. *Figure 8* shows changes in water storage capacity by sub-watershed. **Areas of historical losses in water storage capacity** on the landscape include:

- Wetlands that historically occurred in the City of Calgary, but are no longer present in the southwest corner of the study area;

- The large wetland that once occurred along the Shepard Ditch immediately south of the large Shepard Slough complex in Rocky View County, which appears to have been drained during Shepard Ditch upgrades within the trend analysis period;
- A large wetland within the Town of Chestermere;
- Several wetlands along the 84th St. industrial corridor north of Shepard; and
- Several wetlands east of the Hamlet of Janet on the east side of the Janet Slough complex.

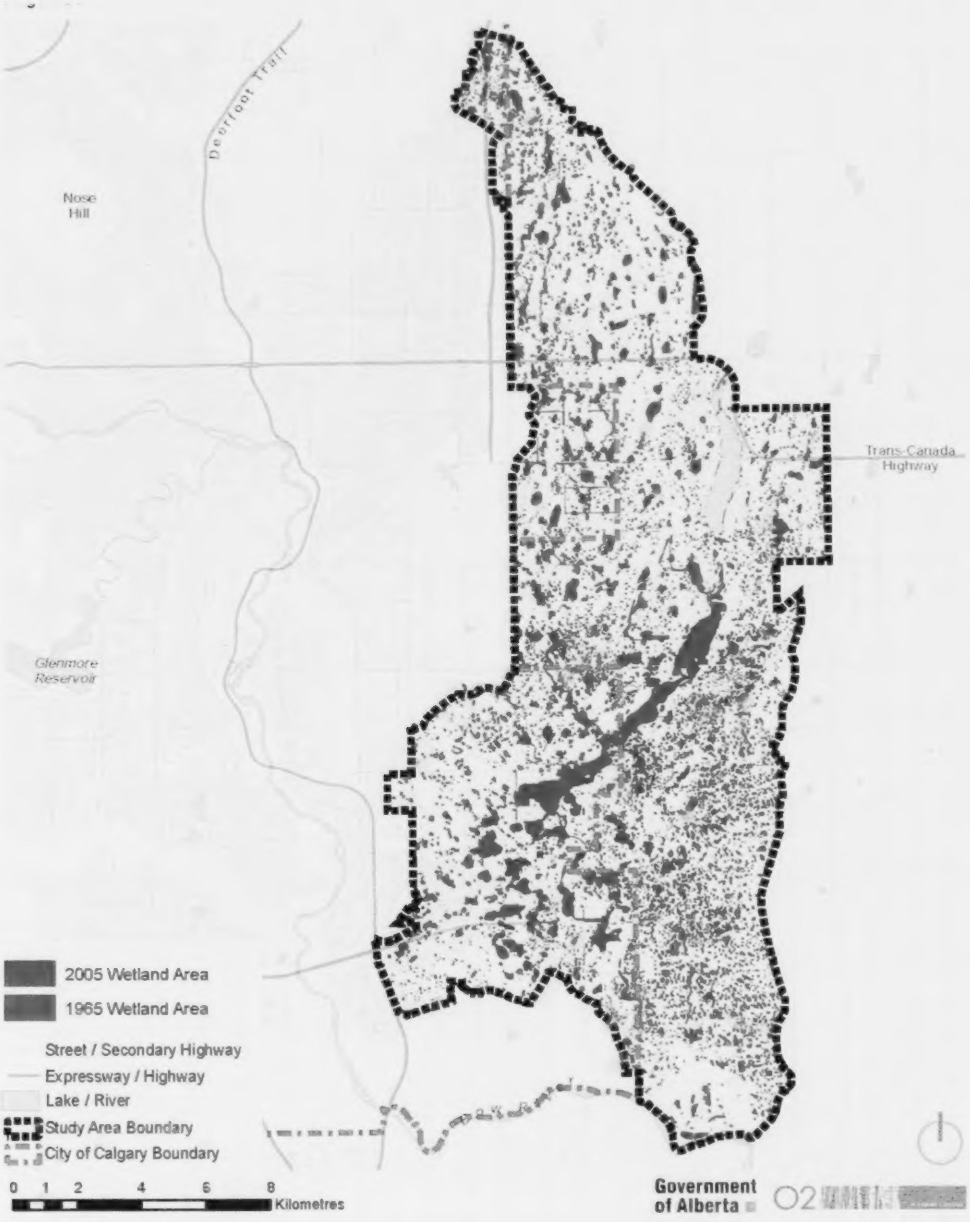

Deerfoot Trail
Nose Hill
Glenmore Reservoir
Trans-Canada Highway
2005 Wetland Area
1965 Wetland Area
Street / Secondary Highway
Expressway / Highway
Lake / River
Study Area Boundary
City of Calgary Boundary
0 1 2 4 6 8
Kilometres
Government of Alberta
O2

Figure 7. Area of wetlands in 1965 vs. 2005

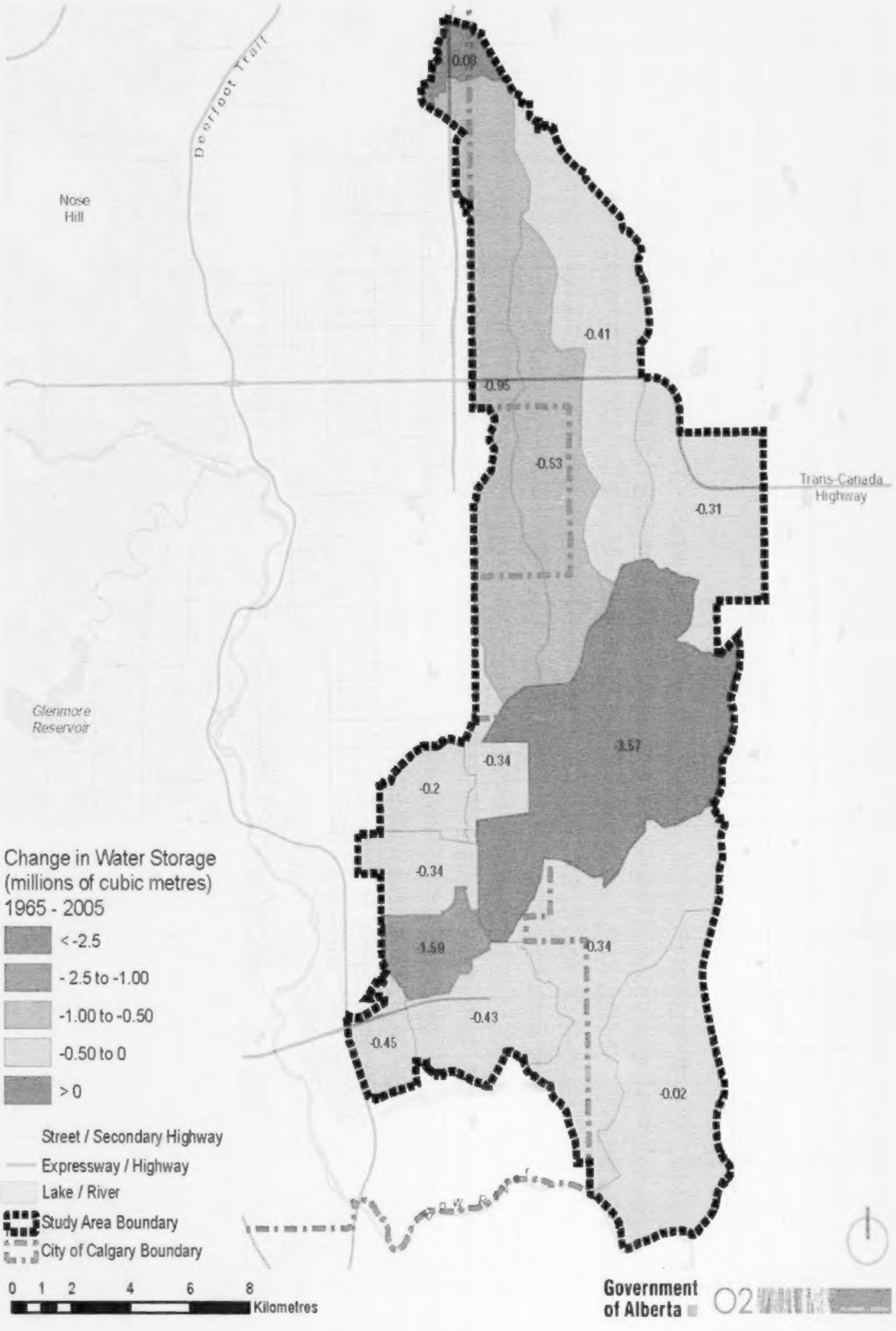

Deerfoot Trail
Nose Hill
0.03
-0.41
-0.95
-0.53
Trans-Canada Highway
-0.31
Glenmore Reservoir
-3.57
-0.34
-0.2
-0.34
-1.59
-0.34
-0.43
-0.45
-0.02
Change in Water Storage (millions of cubic metres) 1965 - 2005
< -2.5
- 2.5 to -1.00
-1.00 to -0.50
-0.50 to 0
> 0
Street / Secondary Highway
Expressway / Highway
Lake / River
Study Area Boundary
City of Calgary Boundary
0 1 2 4 6 8
Kilometres
Government of Alberta
O2

Figure 8. Change in water storage by sub-watershed

3.1.4 Implications of changes in water supply/storage for human well-being

There has been substantial change in the storage capacity of wetlands in the case study area due to historic losses of wetlands. Water storage is a critical ES of wetlands because, as mentioned in section 3.1.1, without water there is no wetland. The observed trend of decreasing water storage on the landscape, which is concentrated in certain areas and highly affected by increasing residential development, is **likely to impact all the benefits provided by wetlands** that are presented in this report (MA 2005). From a cumulative effects management perspective, the loss of water storage capacity due to the drainage of wetlands of all sizes is likely to add up to important cumulative losses of multiple ES. Areas that have historically seen large losses in water storage are thus more likely to also experience changes in soil moisture, micro-climate, flood control and other ES (Gordon *et al.*, 2009). The ecological impacts of cumulative water storage loss have not been investigated for the study area.

While direct human consumption of water from wetlands in the study area is uncommon, wetlands can provide water for domestic, commercial, industrial or agricultural uses. Information on specific water uses within the study area is limited, but suggests insignificant use of wetland water. Six surface water removal licenses are currently held within the study area, three of which may benefit from having wetland complexes nearby that could contribute to water storage on the landscape. There is no available data on whether humans may be benefitting from groundwater (e.g., through wells) in areas where wetlands may be contributing to groundwater recharge. Ranchers are currently the most important consumers of water from wetlands (see Section 3.5.1 on links between agriculture and wetlands). In the future, with declining supply and increasing demands for water, the availability of fresh water from wetlands may become more valuable to supporting human activities in the study area.

Because water from wetlands is generally not consumed directly, it is the role that water storage plays in the support of other ES that is of primary importance for human well-being. Wetlands form an important part of landscape hydrological systems, and their role at the landscape scale needs to be better understood. Studies have shown that wetlands work best to provide multiple ES if they are distributed on the landscape (Mitsch and Gosselink, 2000). The position of a wetland on the landscape and its connectivity to other wetlands and water bodies will affect its importance to landscape hydrology. Further research is needed to understand these connections in the study area.

Engineered stormwater wetlands are often constructed to supplement or substitute for water storage in wetlands. Stormwater ponds have the potential to provide a number of other ES, if they are managed ecologically according to best practices (Moore, T.L. and W.F. Hunt, 2011). This rarely occurs, however, as engineered stormwater ponds are generally managed for flood control and water storage only, leading to poor water quality, basins that do not mimic natural wetland basins and negative impacts on landscape ecology (Forrest, 2010). For example, stormwater ponds can attract aquatic species, but provide poor quality habitat for them due to water quality or other issues (EPA, 1999). While stormwater ponds cannot supply the same bundles of ES that are provided by natural wetlands, constructing stormwater ponds according to best ecological practices could provide both water storage and an improved bundle of other ES. Avoiding wetland loss or restoring natural wetlands can sometimes provide a greater bundle of ES at a lower cost (i.e., the cost and benefits of stormwater pond construction must be compared to the cost of foregoing develop in the wetland area and the benefits from the natural wetland).

3.1.5 Water storage and future research needs

Wetland water storage in the study area has decreased by an estimated 20 per cent since the 1960s. Accelerating drivers of change in the study area suggest that wetland water storage should be monitored in the future, as it is likely to continue on this trend. In addition, hardening of surfaces due to construction and development activities can affect the ability of the landscape to absorb or contain surface runoff. Climate change is expected to change the frequency and magnitude of precipitation events in the future, with more intense storms predicted to occur at higher frequency than is currently the case (AECOM, 2011; Sauchyn *et.al.* 2007). Climate change can also affect the amount of evaporation that occurs on the landscape. All of these drivers of change will result in an uncertain impact on total wetland water storage on the landscape.

Questions that remain about how trends in water storage in wetlands will affect human well-being in the study area include:

- How does wetland water storage contribute to maintaining current hydrological cycles in the region and sustainable water supplies into the future?
- How much of the water supply has been lost or gained over the past decades by agriculture, by transportation infrastructure and by residential developments?
- Whether there are negative impacts to development, economic or other human activities in areas where wetlands have been lost?
- Do tipping points exist in wetland water storage loss, where drying trends could result in the rapid and irreversible loss of other wetlands and wetland ES?
- Is wetland water use likely to increase in the future under scenarios of water shortages?
- How does the amount of water stored in a wetland relate to its ability to provide different ES? Is it simply the presence/absence of wetlands that is crucial rather than the amount of water stored?
- Where is water storage in wetlands most needed to support sustainable human activities?

3.2 ES: Flood Control

3.2.1 *Description of flood control ecosystem service*

Flood control benefits individuals, communities, businesses and governments that must pay the costs of damages when flooding occurs. Wetlands provide mechanisms for flood control by slowing down, absorbing and storing surface run-off (Adamus, 2011), and wetland alteration has direct effects on the incidence and magnitude of flood events (MA, 2005). Although an isolated wetland may perform significant flood control function, effective control is more often the result of the combined effect of a series of wetlands within a particular catchment area (Verry and Boelter, 1978).

Flood control potential can be estimated by the ‘residence time’ of reservoirs and soils, which is the time taken for water falling as precipitation to pass through a system; the longer the residence time, the larger the buffering capacity to attenuate peak flood events. Clay soils, that are predominant the study area, contribute to longer residence times (MA, 2005).

In the case study area, flooding has long been an issue, with flood incidents reported regularly over the past century. In the past ten years, flood risk in this area is increasing in accordance with the growth in industrial and residential development; however, it is not consistent across the whole area (Jiang, 2011). This is likely due to an increase in impervious surfaces from residential development, the removal of wetlands and climate change, although no studies have been conducted to establish causal effects.

Isolated prairie potholes that are predominant in the study area typically form no surface connections to the stream network at average water levels, and thus can be effective at flood attenuation (Murkin, 1998; Brunet, 2011). A prairie pothole will store water up to a certain threshold beyond which it will spill over to a down-gradient receiver (Leibowitz and Vining, 2003; Brunet, 2011). The volume of storage available in prairie potholes isolated from the stream network depends on previous runoff and climatic conditions. Potholes are most effective in flood attenuation when they have a high capacity to store additional water, for example in early spring (McAllister *et al.*, 2000). In addition, they are more or less valuable for flood control depending on where they are located on a landscape and within a watershed. Therefore, although water storage functions as described in Section 3.1 are also directly related to flood control, flood control assessment requires a more detailed consideration of the landscape context of wetlands, for example if they are situated higher or lower in the watershed.

3.2.2 Method of assessment of flood control

Flood control was assessed using a modeling approach based on the Industrial Heartland GIS model developed by Cobbaert *et al.* (2011) shown below. Several modifications and improvements were made to account for study area characteristics and to be able to estimate peak flow (cubic metres per second) reductions. In order to estimate flood control, values for water storage capacity (H1, cubic metres), area of impervious surfaces (H2, per cent), wetland catchment size to wetland ratio (H3), amount of upslope wetlands (H4, per cent), wetland position in watersheds (H5a, quartiles) and subwatersheds (H5b, quartiles), connections to surface waters through natural or artificial drainage systems (H6, presence-absence outflow), and subsurface storage potential (H7, score out of 4 based on vulnerability maps) were calculated for each wetland in the study area. Values for each of these variables were combined to estimate flood control, using the following equation:

Wetland Index of Flood Control

$$\frac{\boxed{H1} + \boxed{H2} + \boxed{H3} + \boxed{H4} + \boxed{H5a} + \boxed{H5b} + \boxed{H6} + \boxed{H7}}{\boxed{8}}$$

3.2.3 Condition and trends in flood control

Figure 9 shows the flood control values for each wetland within the case study area. A large cluster of wetlands near the north boundary of the area was found to have very high capacity to control flood events. Other ‘hotspots’ for flood control occurred east of Chestermere and in the north half of the Belvedere Area Structure Plan area within the City of Calgary. Other wetlands with high flood control values were dispersed throughout the study area. All wetlands were found to have the potential to provide some measure of flood control, but to differing degrees. It is noteworthy that many wetlands exhibit very different scores for different flood control predictor variables (H1 through H7). For example, the large wetlands in the central Shepard Slough complex have large storage capacities (H1), but low scores for many other predictor variables.

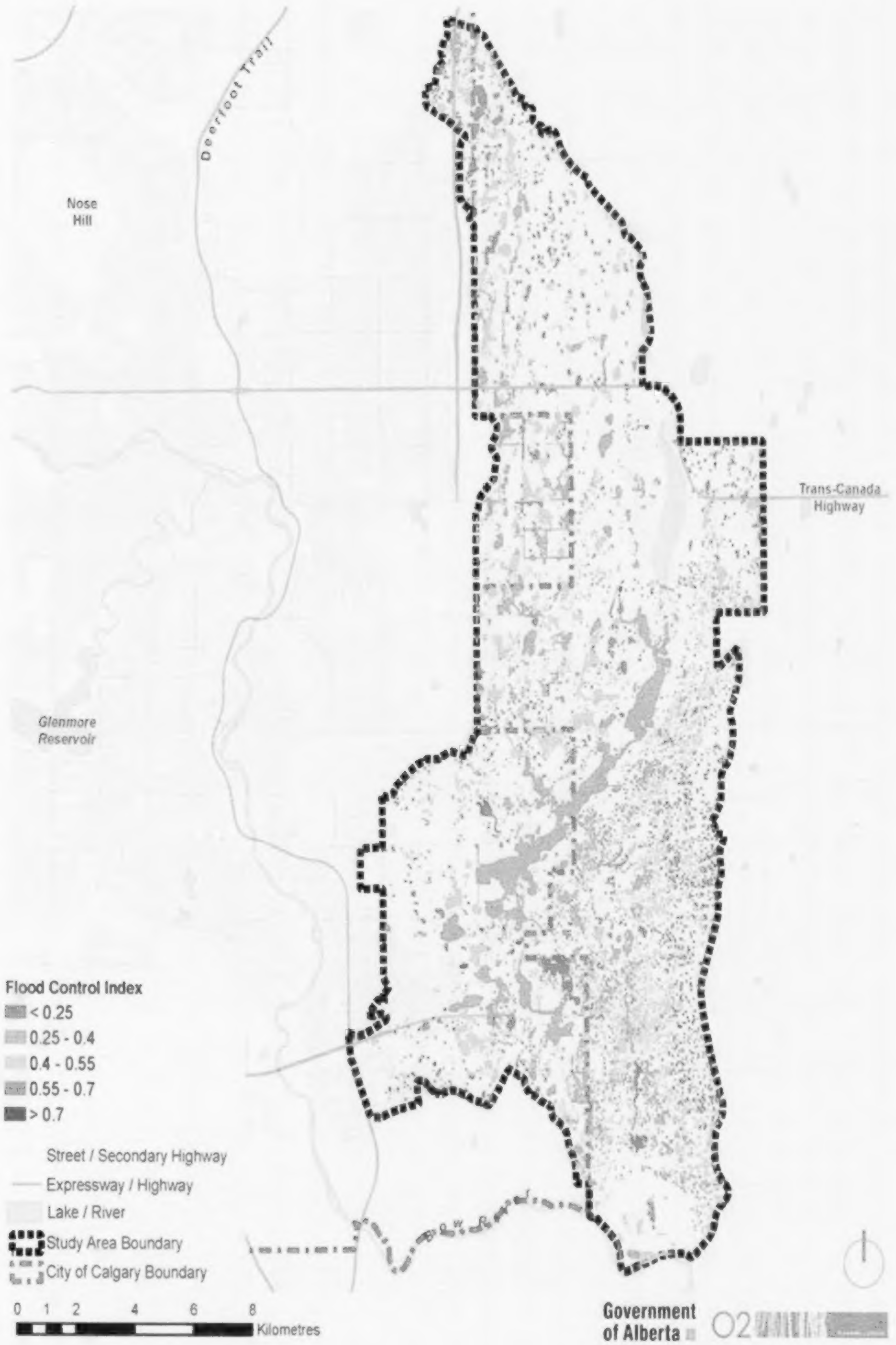

Deerfoot Trail
Nose Hill
Trans-Canada Highway
Glenmore Reservoir
Bow River
Flood Control Index
< 0.25
0.25 - 0.4
0.4 - 0.55
0.55 - 0.7
> 0.7
Street / Secondary Highway
Expressway / Highway
Lake / River
Study Area Boundary
City of Calgary Boundary
0 1 2 4 6 8
Kilometres
Government of Alberta
O2

Figure 9. Present flood control values

Flood control values were analyzed by wetland size class and by S&K wetland class. There were no clear trends found for flood control values across either S&K classes or size classes, suggesting that **high or low flood control depends more on landscape context than on size or class of wetlands**. For example, many medium and small wetlands that occur at high landscape positions provide considerable flood control benefits. This can be interpreted from a cumulative effects management perspective as many small wetlands in strategic landscape positions adding up to a large physical quantity of flood peak desynchronization and reduced peak flows in terms of cubic metres per second at catchment outlets.

There is currently no information on how wetlands in the study area have changed over the past several decades in their ability to provide flood control. A trend analysis of flood control over time was not feasible within the time limitations of the pilot project. However, it can be noted that where wetlands have disappeared (see results of water storage assessment, *Figure* 8), flood control benefits have been lost.

3.2.4 Implications of changes in flood control for human well-being

The model results for flood control in the study area identified the flood control potential of each wetland on the landscape; however, they do not indicate whether people are currently benefitting from wetland flood control services. Further work is needed to identify where people, infrastructure or businesses are most at risk from flooding and which wetlands currently provide the most flood control benefits.

We do know that there are multiple beneficiaries of flood control at local to regional scales. Localized flooding has been identified as an issue within the study area itself, and anecdotal sources of information indicate that flooding has been a problem in the area for at least 100 years. The 2001 Shepard Plan (City of Calgary and Rocky View County 2001) noted that:

- Drainage and flooding are issues in the area;
- The Hamlet of Shepard is located in an area with a high water table, a history of flooding, and water quality problems;
- Stakeholders are interested in how the Shepard Plan could address ditch grading, flooding, flood protection, high moisture problems, high water tables, and water wells; and
- Stakeholders are concerned about road drainage, particularly culverts that are clogged and in poor locations, and water that remains "trapped in ditches".

At the regional scale, the development of the Shepard Ditch towards full capacity means that the once 'non-contributing' case study area will eventually discharge 25-29 cubic metres per second into the Bow River, of which 54 per cent will originate from stormwater within the study area (AECOM 2011). This represents an increase of eight per cent of the flow in the Bow River. Increased peak discharge rates may have impacts on downstream landowners due to increased flooding and erosion of property, including buildings, land, crop, hay and pasture. The drainage of additional wetlands in the study area would result in a further increased discharge rate.

Flood control is an ES that residential development both depends on and impacts. In many cases, wetland drainage and development can cause hydrological changes and local flooding that were not present prior to development. Rocky View County identified the study area as one of the potential flood risk areas and requires that developers are aware of risks and produce the appropriate stormwater management plans to attempt to mitigate some of the risks. Stormwater management systems are typically built to mitigate these impacts, but there can be significant costs in the design, building and maintenance. For example, to enable continued development within the study area while avoiding flooding and drainage problems that occurred in the past, the City of Calgary built the Shepard Stormwater Diversion project at a cost of approximately $60-70 million. The total cost of future stormwater servicing for planned infrastructure in the study area is $270 million (AECOM, 2011). In addition, development proponents need approvals to ensure that pre-development and post development flows are equivalent and permitted (zero discharge rate), and the county regulates remediation and engineered wetland standards, classification of wetlands and compensation requirements, and illegal pumping and filling (Jiang, 2011). Regulatory processes are also costly for both developers and government.

The cost of replacing natural wetlands with built infrastructure was investigated by the ES pilot to determine the total economic benefits provided by wetlands in the study area. This type of analysis provides an idea of how much society is willing to pay for flood control services. The economic benefits of wetland flood control were evaluated based on data available from the Shepard Constructed Wetland. This 230-hectare constructed wetland receives stormwater runoff from a catchment area of nearly 6,000 hectares, and is designed to manage and treat stormwater before eventual discharge to the Bow River. It has a maximum storage volume of nearly 7,000,000 cubic metres and is capable of storing approximately 27,000 cubic metres/hectare for 72 days (AECOM, 2011). The total cost of the project was $58 million, or about $252,000 per hectare[13].

Per hectare water retention capacity of this constructed wetland was applied to the results of the pilot flood control and water storage assessments to estimate the total area of engineered wetlands that would be required to provide the same flood control services that are currently supplied by natural wetlands. Multiplying the per-hectare value from Shepard Constructed Wetland to the estimated 1,339 hectares of wetlands yielded a **replacement cost of about $338 million**. This corresponds to an estimated **$2 million per year in economic losses** if the historic rate of wetland loss is applied (0.6 per cent between 1960 and 2005).

Wetland restoration costs are considerably less than the cost of constructing artificial wetlands of the same size (Tracy Scott, 2011). Based on the historic data on wetland restoration cost from DUC (2005-2011), the average restoration cost of impacted wetlands is $23,284 per hectare. If applied to the pilot results for water storage and flood control potential, the estimated cost of restoring all wetlands on the landscape would be **$43 million**. This corresponds to an estimated **$257,250 per year in restoration costs** if the historic rate of wetland loss is applied (0.6 per cent between 1960 and 2005).

Another way to look at the benefits provided by wetland flood control is to examine damages incurred by flood events. As a large proportion (57 per cent) of the case study area is agricultural, flood risk is a major concern. From 2000 to 2010, total insurance payments to agricultural operations amounted to $385,715 for loss due to flood damage, including $191,991 for the unseeded loss in the spring as a result of too much moisture and $193,724 for flooded loss in the fall during harvest (Rob Cruickshank, 2011). Data on insurance payments for flood damage in residential areas was not available.

---

[13] The land acquisition cost is assumed to be included in the total cost.

3.2.5 Flood control and future research needs

Flood control is very important to the well-being of communities in the study area, and the risk of flooding is understood for a number of reasons:

- municipalities have observed and communicated this trend;
- investment in flood control infrastructure is continuing; and
- further development means an increase in impervious surfaces that in turn increases flooding potential.

Wetlands of all sizes contribute to flood control, and it is likely that connected wetland complexes and wetlands in strategic areas of the case study are of critical importance to the provision of this ES and could contribute to flood control in areas with new residential developments. In calculating the trade-offs between development that incorporates natural wetlands and development that replaces wetlands with flood control infrastructure, it is important for decision makers to take into account the multiple ES provided by natural wetlands vs. infrastructure that provides only the single service of flood control.

Because no assessment of how wetland flood control has changed over the past several decades was conducted, we could not quantify the impacts on flood control from changes in the number and distribution of wetlands on the landscape. Further hydrological modeling would inform decisions on how critical individual wetlands or wetland complexes are to flood control in particular areas of the landscape (e.g., upstream wetlands), and where areas of high risk for flooding are located. Further modeling would also increase understanding of the impacts that flooding has on the quality and flow of the Bow River, which ultimately can impact aquatic ecosystems, human health and lead to higher costs of water treatment. AEW's Wet Areas Mapping (WAM) Initiative will also aid in planning for development that minimizes impacts on water resources.

From a cumulative effects perspective, our findings show that many small wetlands act in conjunction to contribute to a large physical quantity of flood peak desynchronization and reduced peak flows. Monitoring of flood events and how they are mitigated by wetlands would improve understanding of how wetlands contribute to flood protection. Currently, there is no monitoring of flood events in the study area and responses to flood events have been organized on an incident-to-incident basis (Jiang, 2011).

Questions that remain about how trends in flood control by wetlands will affect human well-being in the study area include:

- What areas are at the greatest risk from flooding?

- What are the risks and costs to developers and government associated with removing individual wetlands that provide flood control in conjunction with other wetlands and wetland complexes?
- Can we locate and quantify the potential impacts of a sub-division development project on local and regional flood control capacity?
- What wetland components (i.e. vegetation surrounding wetlands, position of wetland, etc.) are the most important to manage for flood control?
- How do the costs and benefits of engineered flood control infrastructure compare to the opportunity cost associated with maintaining wetlands on the landscape and the multiple benefits provided by wetlands? Is there an optimal middle-ground that minimizes trade-offs associated with development, flood control and the provision of bundles of ES?

3.3 ES: Water Quality/Purification

3.3.1 Description of water purification ecosystem service

Wetlands purify water, and people benefit from this ES through the provision of cleaner water for drinking, for recreation, and to support beautiful and biodiverse wetlands to visit and observe. Purification occurs when water infiltrates soils where pollutants are removed by adsorption to soil particles and/or absorption by living organisms in the soil or water. Wetland water purification is a function of the rate of water movement through the system and the integrity of purification processes related to the affinity of substrates to adsorb or absorb contaminants in the water.

The assessment of wetland purification for the ES pilot focused on the removal of sediments and nutrients (i.e., nitrogen and phosphorus) from the water supply, as these are the most important pollutants in the study area.

There are three zones around a wetland that contribute to water purification: the emergent zone, wet meadow zone and riparian upland zone. The most important part of a wetland in the context of water purification is the riparian area immediately adjacent to it. In many landscapes a riparian area of adequate width can be very effective at reducing nutrient, pollutant and sediment loads before they reach the wetland itself. As a result, removal or alteration of riparian areas (e.g., wet meadow zone, riparian shrub and forest zones) reduces the ability of wetlands (as well as streams and rivers) to purify water. The species composition and biodiversity within riparian zones plays an important role in the sediment and nutrient retention potential of the wetland. Many studies exist demonstrating the purification potential of different species (e.g., Picard *et al.*, 2005; Zedler, 2000).

Many changes have occurred in the drainage of the study area over the past century, raising concerns about water quality impacts to the Bow River, which now receives water from the study area through the Shepard Ditch. Increased stormwater flows into Chestermere Lake have decreased the water quality of the lake, to the concern of local residents that use the lake for recreation and enjoy its beauty (AECOM 2005). Agricultural practices have also added nutrients to the soils and water for over a century.

Apart from a water quality measurement station at Chestermere Lake, there are no other monitoring stations that can provide water quality indicators regarding the impact of agriculture, infrastructure and residential development within the study area. From water quality monitoring stations on the Bow River, we do know that the City of Calgary and abutting lands have a significant negative impact on the water quality of the Bow River, leading to seven fold increases in total phosphorus and total nitrogen and doubling of chlorophyll – *a* and turbidity levels (*Figure* 10).

The total contribution of wetlands to water quality within the study area is unknown. In areas that have been highly developed resulting in increased urban run-off, individual wetlands may not be able to absorb high levels of pollutants and risk becoming polluted stormwater ponds. Constructed wetland complexes are being used to supplement water purification in the study area. For example, the Stormwater Diversion Project diverts stormwater from parts of the City of Calgary away from Chestermere Lake into a constructed wetland complex. These constructed wetlands will ultimately treat more than 50 per cent of the stormwater from Calgary's east industrial parks as well as subdivisions to the north (AECOM, 2011).

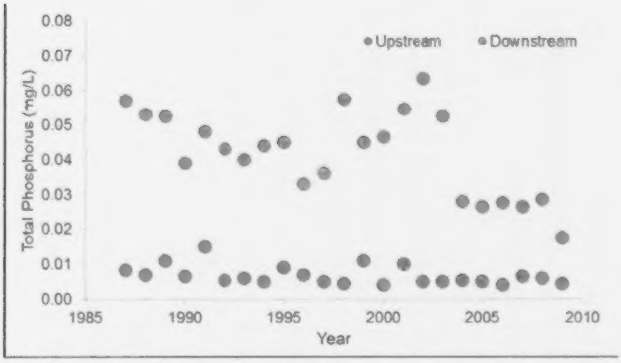


Figure 10. Time series of water quality at government water quality monitoring stations at an upstream (Bow River at Cochrane - AB05BH0010) and downstream (Bow River below Carseland Dam - AB05BM0010) location to the study area. Data points reflect annual median of approximately 12 water quality measurements taken at monthly intervals. Downstream Total Phosphorus values are approximately seven times the upstream value.

3.3.2 Method of assessment of water purification

The assessment of water purification in this pilot project focused on the potential of wetlands to remove sediments and nutrients (i.e., nitrogen and phosphorus) from a water supply. The Wetland Purification Score, calculated for all wetland complexes in the study area, is based on an index derived from eight[14] metrics that describe water purification potential:

- Wetland area; total area of wetlands within a wetland complex (WP1, hectares)

---

[14] A more advanced, and potentially accurate, model was also developed using 39 metrics, however, the data was not available within the timeframe of the pilot assessment. The more advanced model includes metrics for riparian vegetation, soil composition, surrounding land cover, surrounding land use, groundwater vulnerability, and many more.

- Pollutant sources; percentage of wetland contributing area that is under urban land use (WP2)
- Pollutant removal opportunity; index of wetland area to wetland contributing area ratio, percentage disturbed land, and wetlands upslope of wetland complex (WP3)
- Pollutant transport potential; mean slope of wetland's contributing area (WP4)
- Potential significance of purification; distance from wetland complex to stream/river (WP5)
- Recharge potential; position of wetland complex in catchment (WP6)

The metrics were determined using satellite imagery (LANDSAT TM), climate data (LANDSAT TM), a digital elevation model (LiDAR), zonal statistics in ArcGIS and LiDAR data collected in the Fall (2007-2009). Wetland inventories were completed for 1990, 2000 and 2010 using LANDSAT TM, choosing periods with similar climate conditions[15].

The Wetland Purification Score (WPS) was determined using the following formula:

Wetland Purification Score

$$\frac{\boxed{WP1} + \boxed{WP2} + \boxed{WP3} + \boxed{WP4} + \boxed{WP5} + \boxed{WP6}}{\boxed{6}}$$

3.3.3 *Condition and trends in water purification*

The majority (**87 per cent**) of wetland complexes within Shepard Slough have **a medium to high wetland purification score (0.4 to 0.7 out of 1.0)** (*Figure 11*). No wetland falls in the highest category (WPS = 1.0) or in the lowest categories (WPS = 0.1, 0.2). Wetland purification scores generally follow a similar trend throughout the time series with scores typically in the medium to high range of values.

Figure 12 shows the change in wetland purification scores of wetland complexes throughout the trend period. Those wetlands that show a reduction in WPS (indicated in orange) are likely the result of removal of wetlands following urbanization. In 2010, there is a general **shift towards higher wetland purification scores**. The increase in wetland purification scores for 2010 is either due to an increase in wetland area (more wetlands were captured in the 2010 satellite-based wetland inventory used in the model) or in the purification value to humans resulting from an increase in urban land use in the study area. In the model used, as wetlands become scarcer, remaining wetlands become more valuable for their services. This is a function of the model set up that measures the ES in its capacity to provide benefits to humans, and not only reflects the ecological capacity of a given wetland to purify water.

---

[15] For future ecosystem service assessments, it is recommended that a combination of LiDAR, Landsat/SPOT, and SAR imagery are used to map wetlands (both inundated (open water) and saturated areas), and determine their spatial and temporal dynamics over changing climatic conditions and response to human activities. This was not possible for the ES Pilot.

It is important to note that while it is true that scarcity makes remaining wetlands more valuable to humans, the capacity of remaining wetlands to compensate for the loss of the other wetlands is limited. Wetlands can perform important water purification services until they are overloaded with pollutants and their function is reduced.

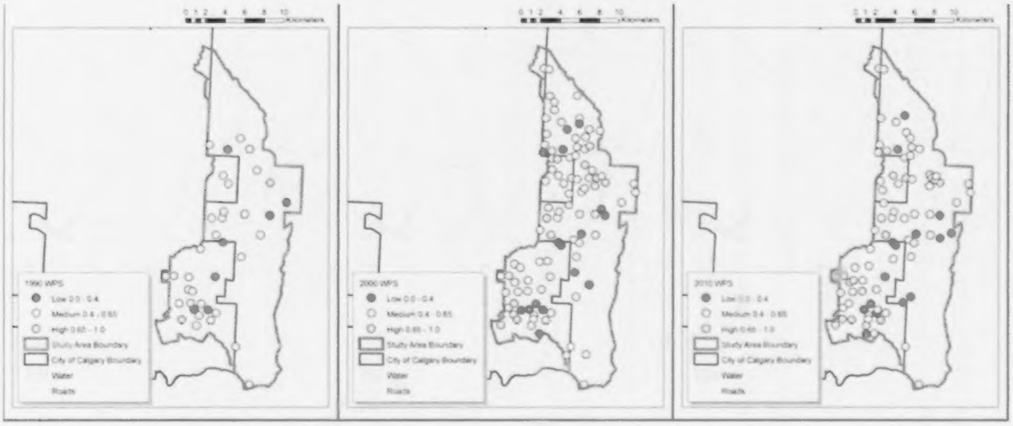


Figure 11. Wetland purification scores for wetlands in 1990, 2000 and 2010

There are a number of limitations to discussion regarding this particular model. Observing trends in wetlands is challenging as results will differ depending on the season that data is collected and underlying climate trends. The Landsat inventory applied defines only the inundated (open water) zone of wetlands within the study area, and does not include the saturated zones that play an important role in water purification through nutrient uptake and absorption. Both the inundated and saturated zones provide different functions in terms of water purification. For example, inundated areas are important for P removal whilst saturated areas are important for N removal. This “complementary” role of inundated and saturated areas in water purification processes prevents definition of wetlands using inundated area alone from fully capturing the range of wetland function. As a result, the Landsat inventory provides a conservative estimate of wetland size and abundance. Notes on these and other challenges and recommendations for future ES work on water purification are provided in supplementary reports prepared for the pilot, as discussed in the About the Report section.

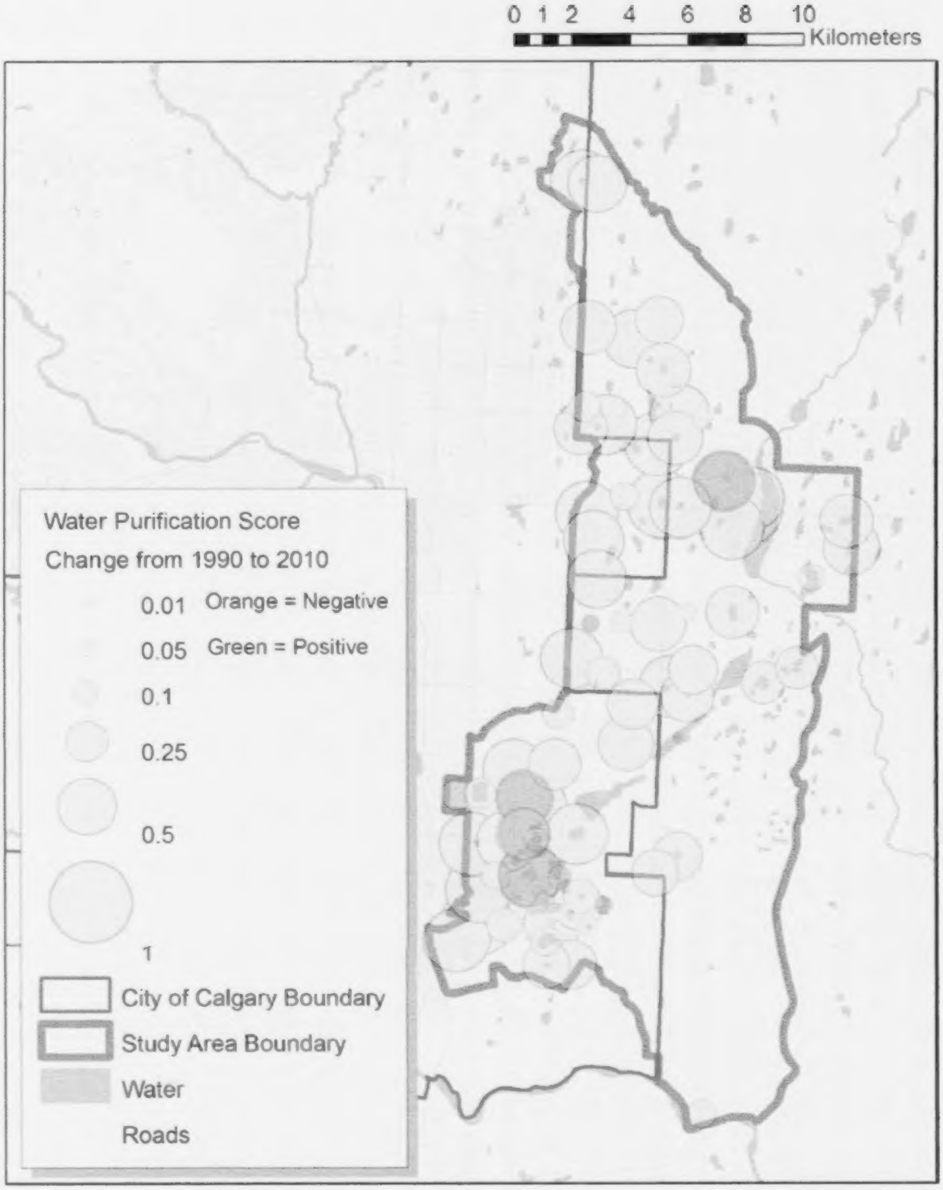

0 1 2 4 6 8 10
Kilometers
Water Purification Score
Change from 1990 to 2010
0.01
0.05
0.1
0.25
0.5
1
Orange = Negative
Green = Positive
City of Calgary Boundary
Study Area Boundary
Water
Roads

Figure 12. Changes in wetland purification potential from 1990 to 2010. Orange circles represent a loss in water purification potential, while green circles represent a gain in water purification potential; the larger the circle, the larger the gain or loss. For example, a circle corresponding to the legend size of 0.5 has experienced a 50% gain in water purification potential.

3.3.4 Implications of changes in water filtration/quality for human well-being

The water purification model proposes that all the wetlands in the study area provide moderate water purification services. However the model used does not provide information on whether particular areas or developments are currently benefiting from water purification and how wetlands impact water quality either in specific locations or at the landscape scale. Better water quality monitoring, more complex models (such as the one suggested in the water purification technical report), and groundtruthing of models are needed to understand how people and communities in the study area benefit from wetland water purification.

Scientific literature suggests that many wetlands distributed across a landscape together provide important water purification services at the watershed scale (Mitsch and Gosselink, 2000). In many agricultural areas across the world, farmers have recently been encouraged to maintain wetlands on the landscape to absorb excess nutrients from agriculture and purify water for multiple beneficiaries. In some landscapes, wetlands are the most cost-effective and sustainable providers of water purification services, especially when non-point pollution sources are a principal problem (Gustafson *et al.*, 2000). As residential development increases, more water purification services are needed. Wetlands that are incorporated into developments can provide water purification services along with other ES. However, research is needed to determine pollutant-loading thresholds and human and wetland density-related thresholds beyond which a wetland can no longer provide water purification or other ES (Mitsch and Gosselink, 2000).

The economic benefits that wetlands provide depend on their geographic and social context. Wetlands can provide economic benefits via avoided water treatment costs. The classic example of quantifying the benefits that humans get from natural water purification processes comes from New York, where the state opted to spend $1 billion to restore the Catskills watershed that provides and purifies New York City's drinking water rather than to spend $8 billion on building a new treatment facility and paying annual operating expenses of $300 million (NYC DEP, 1993).

Constructed wetlands are now used frequently for the treatment of contaminated or nutrient-enriched water. In the study area, wetlands are being modified for nutrient management or replaced by water treatment plants and constructed wetlands and stormwater ponds. Calculating the replacement cost of constructed or modified wetlands and water treatment in plants is a method for determining the value of water purification by wetlands to humans.

For the economic assessment, the pilot estimated the cost of conventional water treatment, constructed wetlands and wetland restoration. Initial construction costs of treatment wetlands are relatively low compared with traditional water treatment systems. Because wetlands require little maintenance, long-term costs are also quite low. The cost of the constructed wetland is proportional to the number and sizes of treatment cells required, generally about 50 per cent to 90 per cent less than conventional treatment techniques (White, n.d.). For the study area, the treatment costs of phosphorus and nitrogen (in terms of $/kilogram) were not available, nor were local data for how much phosphorus and nitrogen a typical wetland in the area can absorb (amounts depend on the particular type of wetland, its location and plant composition, and the chemical and physical characteristics of the soil). The pilot used conservative estimates from a North

American database that have been used previously in the study area: 80.3 kilograms per hectare per year for phosphorus, and 547.5 kilograms per hectare per year for nitrogen. The cost of phosphorus treatment was estimated at $360 - $1764 per kilogram (Kadlec and Knight, 1996; AECOM, 2011). The restoration costs of existing wetlands were estimated in the Section 3.2.4, totaling $257,250 per year if trends in wetland loss continue at the same rate as the past several decades.

Table 4 provides the results of these estimations, showing that wetland restoration is the most cost-effective method of removing phosphorus from the landscape, but that constructed wetlands are still more cost-effective than conventional water treatment approaches. It is important to note that natural and restored wetlands provide more ES than water purification, and these additional benefits should be included in cost-benefit studies for specific wetlands.

Table 4. Type of water treatment option with associated cost to engineer versus cost of lost wetland

Water Treatment Option	Associated Cost ($)	Annual Value Loss (Wetland loss=0.6 per cent)
Wetland restoration	$42,875,000	$257,250
Constructed wetlands	$70,824,600 - $347,040,540	$424,948 - $2,082,243
Conventional water treatment techniques	$141,649,200 - $694,081,080	$849,895 - $4,164,486

3.3.5 Water purification and research needs

The water quality assessment would have benefitted from better knowledge of current water quality in the study area. The assessment evaluated how wetlands are contributing to water quality improvement, but without measured values showing trends in water quality over time in outflows into water bodies it is difficult to ground truth the results. Because this area is now contributing to the Bow River, it may be important to determine what the impact of development in the area is on water quality, and how wetlands contribute to improving water quality before the water enters the Bow River.

Human activities can degrade natural water purification by increasing the proportion of unfiltered water that bypasses the purification system to enter the water supply directly, by overloading the capacity of wetlands to purify water, and by removing purification processes from a wetland. For example, soil compaction reduces the water infiltration capacity of soils, resulting in decreased infiltration whereby polluted water is then delivered directly to surface waters. In the extreme case of impervious surfaces (e.g., roads, parking lots, highways, and buildings that are increasing in number within the study area), all of the water is conveyed quickly into receiving waters or city drains, instead of through soils and wetland complexes where they have an opportunity to be cleaned and purified before entering main water sources. Removing or altering riparian zones around wetlands can reduce a wetlands ability to purify water. Because these types of changes are occurring and will continue to occur within the study area, more research is needed into the relationship between anthropogenic changes, wetland capacity to purify water and water quality across the landscape.

Finally, our results show that removal of wetlands directly decreases water purification services on the landscape. With every wetland removed, there is less capacity on the landscape to purify water. The distribution of remaining wetlands and how wetlands are managed at the landscape scale will determine whether wetlands can continue to provide purification services that improve the well-being of people in the study area. More understanding is needed about thresholds related to the number and distribution of wetlands in this area and the capacity on the landscape to purify water (Mitsch and Gosselink, 2000). Strengths and weaknesses in natural water purification need to be identified in order to address their management effectively.

Questions that remain about how trends in water filtration by wetlands will affect human well-being in the study area include:

- Where is it most useful to monitor water quality in order to inform decision making related to wetland development? What other landscape components need to be monitored (e.g. vegetation buffers, etc.)?
- What is the cumulative impact on wetland water purification capacity of historical and ongoing wetland loss?
- Would an improved model for water quality, already developed for this project but not analyzed due to time constraints, provide more accurate and relevant information for decision makers?
- What is the best model for managing water quality and other ES in the study area, including the management and restoration of natural wetlands, constructed wetlands, and water treatment (acknowledging that run-off in urban areas is often extremely polluted and can overload wetland purification capacity)? Can the above-mentioned model help to determine this?
- What are the contributions to water quality of riparian areas, saturated areas, and other wetland features that are important to specific filtration/absorption functions in wetlands in the study area? Match a literature review to the wetland types and surrounding areas in study area.
- Where do pollutants accumulate on the landscape?

3.4 Carbon Storage

3.4.1 Description of carbon storage ES

Carbon storage is important to the well-being of the global population that benefits from this ES through regulation of climate. Carbon storage plays a role in climate regulation by holding carbon in the ground or in living biomass that might otherwise be released into the atmosphere as a greenhouse gas. Warming trends in the global climate are causing concerns in many places, as warmer climates have been linked to increased frequency and intensity of weather events, natural disasters, economic losses, and ecological changes that have resulted in losses to other important ES (IPCC, 2007).

Although only one per cent of the Earth's surface is covered by inland waters such as ponds, lakes, rivers, streams, and wetlands, these systems play a significant role in the global carbon cycle compared to terrestrial and marine systems (Battin *et al.*, 2009).

Wetlands, which are the interface of aquatic and terrestrial environments, are particularly important in the global carbon cycle. In North America, freshwater mineral soil wetlands account for 18 per cent or approximately 40 gigatonnes (Gt) of the wetland carbon pool (Bridgham *et al.*, 2006), equivalent to 5-6 times the average annual amount of carbon emitted through the Bedard-Haughn *et al.*, 2006). Land cover change from wetland and surrounding grassland to highly developed urban areas entails a large loss of carbon storage, although the change differs depending on management choices during development.

3.4.2 Method of assessment of carbon storage

Carbon storage associated with S&K's Class III (seasonal), Class IV (semi-permanent), and Class V (permanent) wetlands in the case study area was assessed. Class I and II were omitted due to methodology and project limitations.

In order to conduct the assessment, first the stock of carbon contained in existing wetlands within the case study area was estimated, and then the amount of carbon dioxide re-emitted to the atmosphere as a result of wetland loss between 1962 and 2005. In order to estimate carbon stocks, wetland inventories for two periods were constructed. A current wetland inventory was derived from aerial photographs taken in the 2005 growing season. An historic wetland inventory was derived from stereo photographs taken in June 1962 (2011) observed soil organic carbon concentrations (SOC) of 205 Mg C ha^{-1} in reference wetlands.

To conservatively estimate the amount of carbon re-emitted back to the atmosphere as a result of wetland loss in the case study area (specific to class III - V wetlands) we applied an SOC loss of 89 Mg ha^{-1}, as not all soil organic carbon is lost during drainage. This factor is taken from Badiou *et al.* (2011) and was estimated from the differences in SOC concentration between intact wetlands (205 Mg SOC ha^{-1}) and recently drained wetlands (116 Mg SOC ha^{-1}).

3.4.3 Condition and trends in carbon storage

The carbon storage assessment estimated that there were approximately 1,980 hectares of Class 3-5 wetlands in 1962, and this decreased to 1,484 hectares in 2005, for a total change of 496 hectares across the study area. This is equivalent to a **25 per cent loss in wetland area between 1962 and 2005** or approximately 0.6 per cent per year.

A total wetland soil organic carbon pool in 1962 was estimated at 405,818 Milligrams and 304,276 Milligrams in 2005. Soil organic carbon pools in both 1962 and 2005 were almost entirely from wetlands greater than 0.5 hectare in size. The estimated **loss of soil organic carbon between 1962 and 2005 is 44,144** M **(89** Milligrams/ **hectare^{-1}).** This is equivalent to an **emission of 161,832 Tonnes of carbon dioxide equivalent**. To put this figure in context, this amount is also equivalent to the annual greenhouse gas emissions of 31,732 passenger vehicles, or to the carbon sequestered by 4,149,538 tree seedlings grown for 10 years (EPA, 2011).

The loss of soil organic carbon estimated here is likely very conservative. In regions, such as the case study area, where wetlands were drained and either cropped or developed we would expect a larger loss of stored carbon in the soil relative to the average loss estimated from drained wetlands in grassland landscapes.

3.4.4 Implications of changes in carbon storage for human well-being

Carbon storage is an ES that is recognized and consumed at the global scale, and the importance of carbon storage to local people is often unseen and therefore quite small. In some areas of the world, policy incentives are developed to manage carbon pools in ways that benefit local communities or individuals (i.e., government payments for ES).

Climate change has been identified as the cause of higher intensity and higher frequency weather events, such as storms, droughts and floods (MA 2005; IPCC, 2007). Wetland draining decreases methane (CH_4) emissions but increases carbon dioxide(CO_2) and nitrous oxide (N_2O) emissions. While it is difficult to link local trends in climate or weather to changes in global carbon stocks, many countries and regions are developing incentives and regulations to control carbon emissions and maintain stored carbon stocks, recognizing the major impacts on economies and human health that climate change is already having.

Alberta was the first jurisdiction in North America to enact legislation and regulations that require large emitters to reduce greenhouse gas emissions. *The Climate Change and Emissions Management Act* and the *Specified Gas Emitters Regulation* (SGER) require facilities that emit more than 100,000 tonnes of greenhouse gases per year to reduce emissions intensity by 12 per cent annually. Regulated entities have three compliance options: (i) actual reduction in Green House Gas (GHG) emissions intensity based on a facility baseline; (ii) purchase of Alberta-based emissions offset credits; or (iii) purchase of Climate Change and Emissions Management Fund (the ‘Tech Fund’) credits which are presently valued at C$15 per tonne.

The economic value of carbon storage in the study area was estimated by multiplying the stock of carbon stored in the case study area with different values of carbon supplied by the Canadian Council of Parks, generated using different methods for economic valuation (see *Table 5*). Given that there was such a wide variety of monetary value assigned to carbon, the value of carbon storage in the study area ranges from a low of $264,152 to a high of $49,528,500. Alternatively, if we apply the more regionally relevant Alberta Tech Fund value of $15/tonne of carbon dioxide equivalent (CO_2 e), the economic value of carbon storage in the case study area would amount to **$16.7 million**.

Table 5. Carbon storage economic methods and values

Valuation Method	Value of Carbon per tonne of carbon dioxide equivalent (Cdn $)	Value of Carbon Storage
Alternative Cost	$15 – 645	$1,981,140 - $85,189,020
Quasi- Market Method	$15 – 55	$1,981,140 - $7,264,180
Replacement Cost Method	$2 – 104	$264,152 - $13,735,904
Substitute Cost Method	$8 – 375	$1,056,608 - $49,528,500

3.4.5 *Carbon storage and research needs*

The carbon storage assessment provided a conservative estimate of this ES in the study area, as it only included Classes III-IV wetlands. Carbon loss was also under-estimated as there was no average values available for the amount of carbon lost when wetlands in the area are converted to urban areas or cropland. However, the number of wetlands in the study area and the resulting carbon stored by them shows that wetlands are important providers of this ES.

Questions that remain about how trends in carbon storage by wetlands will affect human well-being in the study area include:

- How do local people value carbon storage on their landscape?
- How much carbon storage is provided in Class I and II wetlands?
- How have trends in carbon storage changed in the past 10 years, compared to trends observed between 1962 and 2005?

3.5 Additional Ecosystem services provided by wetland landscapes

The ES team recognized that it could not comprehensively assess all the ES of wetlands in the case study area within the scope of a pilot project. There was significant interest in assessing other ES to the extent possible to create awareness and begin to understand the role that wetlands play in producing multiple ES. This section provides primarily qualitative information on the production of additional ES, with additional results from a ranking survey and economic valuation studies. The information provided in this section is thus less representative of the entire study area than the previous four ES.

3.5.2 Crops/food

Food is an ES that humans consume directly. Food is usually produced with a lot of input from humans (e.g. fertilizer, machinery, etc.), but the provision of food relies on a productive environment with sufficient moisture, suitable soils, pest control and other ES and ecological functions. Very little food is produced in/by wetlands; however there are several connections between wetlands on a landscape and crop and livestock production. Water moves on the landscape between wetlands and adjacent upland soils, which increases the amount of soil moisture available for crop production (Cows and Fish, n.d.; Schroeder and Bauer, 1984; Gilbert *et al.*, 2006). Wetlands also provide a source of water for livestock, for both grazing and hay production. According to Cows and Fish, "vegetation around wetlands can be four to five times as productive as the surrounding uplands". Wetlands provide a source of irrigation water for crops and maintain a high water table that provides other agricultural benefits such as better soil moisture (Cows and Fish, n.d.).

Aside from urban areas within the Town of Chestermere and several development nodes within Rocky View County, the study area is characterized by agricultural operations of either crop generation or ranching (AECOM, 2011). Barley is the predominant crop cover in the area (Dunn, 2011). Ephemeral and temporary wetlands are often cultivated for crop production. The enhanced soil moisture within these wetlands can enhance crop yields, particularly in dry years. Subsurface storage of water is a crucial determinant of crop yields the following growing season (Schroeder and Bauer, 1984).

Hay production within wetlands is also common, particularly in the low prairie and wet meadow zones of all wetland types. However, it is also often the case that excessive moisture in spring as well as wetland soils high in clay may actually reduce crop yields in cultivated wetlands.

Ranchers have been identified as the most common users of wetland water in the study area. A large proportion of cattle may drink from wetlands, including dugouts. The average density of cattle in the study area is 1.66 per hectare across 69,635 hectares of land that can support cattle, resulting in a total of 8,825 cattle. The total water requirement for cattle was estimated to be 132,377 cubic metres/year. This volume represents about 0.37 per cent of the total water capacity of wetlands in the study area and about 0.94 per cent of dry season water availability. It is unknown what proportion of cattle water requirements is met by wetlands vs. other sources (groundwater, streams).

Further study is needed to determine how wetlands and wetland complexes influence hydrology across the whole study area, and how this might impact agricultural practices. Short-term policies that are implemented to enhance food production can lead to unintended consequences for wetland ecosystems, which may produce water quality and availability risks in the long term (MA, 2005). Loss of wetlands can impact soil moisture and lead to declining agricultural productivity in the case study area.

3.5.3 Pollination

Pollination is a regulating ES that underpins the successful production of some provisioning ES, such as fruit and nuts crops. Pollinators are species that carry pollen to enable plant reproduction and agricultural production (NRC, 2007). Bee-pollinated forage and hay crops, such as alfalfa and clover, are also used to feed animals that supply meat and dairy products (NRC, 2007). In addition to harvestable crops, about three quarters of the more than 240,000 species of the world's flowering plants rely on pollinators (NRC, 2007), making pollination an ES that underpins many cultural ES that are related to aesthetic values, recreation, and science. Bees are the dominant taxon providing crop pollination services, but birds, bats, moths, flies and other insects can also be important (Kumar, 2011).

Bees enable the production of an estimated 90 commercially grown crops, some of which are grown in the study area. In 1998, the value of honeybees as pollinators for Canadian crops was assessed to be $782 million (Canadian Honey Council, 2001). In Southern Alberta, the cultivation of canola seeds, which requires pollinators, is an important agricultural activity. In the study area, canola and other oil seeds are the second largest agricultural activity by land use after the cultivation of cereal crops (SLC Agricultural Data, 2006). A large amount of pollination occurs with the aid of commercial bee colonies, but a portion of crops are pollinated by native species. In 2008, there were 80,000 bee colonies under contract for the purpose of pollination in southern Alberta (Canadian Honey Council, 2009).

Pollination is important to the resilience of all ecosystems, and native pollinator species require natural/semi-natural habitats for nesting (e.g., in tree cavities) and floral resources not found within crop fields (Kumar, 2011). Research indicates decay in pollinator richness and native pollinator visitation rates with distance to natural or semi-natural habitats from agricultural areas (Kumar 2011). Because of increasing costs associated with managed pollinator species from commercial crops (i.e., higher pollinator rental fees) (NRC, 2007) and the sudden declines in commercial bee populations, agricultural systems that maintain native pollinator species may be more resilient in the long term. Wetlands and wetland-adjacent grasslands provide suitable habitat for native pollinator species.

3.5.4 Soil formation, Erosion Control and Sediment Retention

Soil-related ES including, soil formation, erosion control and sediment retention, are crucial for supporting many land uses and land covers, water quality and for producing critical provisioning services such as crops. Soil formation refers to the process of soil creation from such processes as weathering rocks and the accumulation of organic material. As noted in Jared Diamond's famous "Collapse" the destruction of soil has led to the demise of several nations and civilizations (Diamond, 2006).

The soils within the case study area directly benefit humans through provision of agriculture commodities. These soils are amongst the best available for crop and forage production in Alberta (AARD, 2001), with soil horizons that have evolved over past millennia. The soils in the case study are Black Chernozemic and are found in 16 per cent of the agricultural land on the prairies (AC, 2000).

> *"More than 300 million acres out of our 400-odd million acres of farm fields are now eroding faster than soil is being formed. That means destruction of the land if erosion is not controlled… Here in a nutshell, so to speak, we have the underlying hazard of civilization. By clearing and cultivating sloping lands—for most of our lands are more or less sloping—we expose soils to accelerated erosion by water or by wind and sometimes by both water and wind." (Lowdermilk, 1953, p. 27).*

Erosion control and sediment retention were ranked among the six most important ES in southern Alberta (2007 Ecosystem Goods and Services Assessment - Southern Alberta Phase 2 Report: Conceptual Linkages and Initial Assessment (Phase II, Version II)). In the study area, there is a pattern of land use change from agricultural to urban, as rich agricultural soils are converted into urban landscapes. In North America the soil conversion record over the past 300 years is unprecedented in the global history of land development due to technology and population growth.

Wetlands play a role in producing highly productive soils. In the case study area, as is typical of the prairie pothole region, there are many depressional storage areas on the landscape – some are wetlands and some are small natural undulations in the landscape. These depressional areas provide erosion control and sediment retention capacity. Wetlands act as settling areas and prevent sediment from reaching waterways. Indentations on landscapes are important for infiltration, which means water is kept in place versus moving overland with sediments in tow.

The riparian zone/ wetland margin is of particular importance for erosion control and sediment retention, linking these ES strongly with the service of water filtration/quality that is assessed earlier in the report. In Alberta, the importance of keeping cows out of riparian zones to prevent erosion and control sediments has been recognized. Erosion control and sediment retention also occur within stormwater ponds, although flooding events can flush sediment into neighbouring water bodies without obstruction, as there is little vegetation around the concrete infrastructure of these ponds. In addition, constructed wetlands are often contaminated due to their location in urban areas and the lack of flushing. Once they are full, a maintenance plan is needed in order to deal with sediment accumulation.

3.5.5 Cultural ES: Science and Education, Tourism, Heritage Values, Aesthetic Benefits

Cultural services are described as the "nonmaterial benefits obtained from ecosystems" (WRI, 2008) where services and related benefits are, for the most part, contingent on various human activities or experiences occurring in a particular setting. As noted earlier in the report, the provision of different ES are often interconnected, and many cultural ES are provided simultaneously (e.g. recreation and aesthetic appreciation around a wetland) as well as relying on other types of ES (e.g. both recreation and aesthetic appreciation rely might rely on good water quality). More information on cultural ES can be found in the Socio-Cultural Technical Report.

The results of a socio-cultural survey completed for the ES pilot showed that people in the study area have both biocentric and anthropocentric views about wetlands. Across the survey sample (n=160), some of the biocentric (or nature-centered) statements included:

> "*Wetlands are sacred places*"
> "*Wetlands give us a sense of peace and well-being*"
> "*It is important to maintain wetlands for future generations.*"

Statements that appeared to be anthropocentric (or human-centered) included:

> "*Wetlands should exist mainly to serve human needs*"
> "*The primary function of wetlands should be to provide products and services that are useful to humans*""
> "*Wetlands that are not useful are a waste of our natural resources.*"

It was clear from survey results that cultural ties to certain natural features on a landscape can be powerful and lead to long-term emotional connections with a place (Kellert, 2004). These benefits can have powerful impacts on a person's well-being and therefore can be an important factor to consider in decision-making.

This section provides an overview of cultural services provided by wetlands in the study area. It should be noted that in the literature the use of cultural ES, benefits and values are sometimes used interchangeably, which can cause confusion. The ES team recognizes that more work needs to be done on clarifying how cultural ES should be understood and assessed as the ES program goes forward. The ES of focus for the cultural section include tourism and recreation, education and science, heritage and aesthetic.

3.5.5.1 Tourism & Recreation

Tourism and recreation refers to the opportunities provided by wetlands and surrounding landscapes for outdoor recreation and related activities for local people and visitors from a distance. Some recreational activities are quite active, like hiking or biking in wetland landscapes. Dozens of provincial and local nature clubs conduct recreation-related activities (e.g. birding, hiking) within wetlands and other natural areas; these groups include Nature Alberta, Nature Calgary and the Calgary Bird Banding Society. Wildlife viewing is an important recreational activity in wetlands that has witnessed increasing participation locally and across North America in recent years. Hiking, photography and wildlife viewing may often be undertaken in groups, on trips that can extend across large distances, access permitting.

The pilot completed an economic valuation study of bird watching in the study area. The case study area is recognized as a significant birding area where thousands of migratory birds stop over during their annual flights. Many Nature Calgary birding members visit this area regularly, although development is leading to fewer birding opportunities (City of Calgary, 2011).

Recognizing the importance of wetlands and birding opportunities, the City of Calgary developed Ralph Klein Park (RKP), a constructed wetland complex for recreation, education and tourism (Hart, 2011). Ralph Klein Park is a 30.35-hectare Calgary regional park featuring an engineered wetland that uses natural vegetation to treat stormwater before it is discharged into the Bow River. RKP was not fully operational at the time of this study and therefore the collection of economic data was incomplete. Information from other studies and reports were used to establish the base assumptions guiding the economic valuation.

The economic valuation study estimated the number of people partaking in wetland recreation trips for birding and the recreation value of specific wetlands associated with Ralph Klein Park (RKP) for birding. Data was collected from on-site surveys of visitors to RKP and Inglewood Bird Sanctuary (IBS) to input into two economic models – Gravity Model and Travel Cost Model (please see Economic Technical report for more detail). The Gravity Model (Saunders *et al.*, 1981) was used to estimate the potential number of birding participants from the city of Calgary and the Travel Cost Model is an established stated preference value estimation method used widely in recreation value studies (Ward and Beal, 2000).

From these models, a potential value for recreation in the case study area was estimated at $4,390,000 per year. This result is based on an estimated 114,685 visitors to RKP each year, and per person spending of $38.28 for a day trip. Once RKP is fully operational and awareness of the recreational opportunities increases, the number of visitors could increase. In addition, the only recreation activity included in the economic modelling was birding. The choice of excluding walking and other scenic viewing as recreational activities results in an undervaluation the benefits from RKP/case study area.

These results, as a first step, show that recreational opportunities from birding in the case study area has a potential value that warrants attention when planning and approving wetland applications.

3.5.5.2 Education and Research

Wetlands and surrounding areas provide settings for learning about nature, ecology, land stewardship, conservation and other subjects. Scientists can conduct research and experiments in these settings. Respondents to a socio-cultural survey on wetlands conveyed that wetlands were important places because they can provide learning opportunities. Some respondents stated that they brought their children to wetlands, to learn about birds, mammals, and plants, whereas other respondents stated that there needed to be more educational and research activities in wetlands, in order to continue to learn about the biological functions of these places.

Nature related groups that frequent the case study area are focused on missions and objectives such as:

- "Encouraging the appreciation, observation, study, conservation and protection of all components of the natural world"
- "To provide publications and educational opportunities"; and
- "To promote the collection of natural history observations for statistical and educational purposes" (Nature Calgary, n.d.).

An economic analysis of the perceived value of wetlands to education and science focused on Ralph Klein Park (RKP). RKP is an important new nature area for providing educational and interpretive programs about wetlands to visitors and serves as a scientific benchmark for research into natural processes and human-derived ecological change related to wetlands.

Since it's opening to the public in 2011, RKP has received visits from individuals, schools, and also professionals from other jurisdictions to educate themselves on building similar parks (e.g. Boston, US) (Thompson, 2011b). The school visits data provided by the City of Calgary indicate that in the school year of 2011- 2012, 19 schools scheduled visits to RKP (McColl, 2011). An estimated 10,550 students are expected to visit the park in 2012 to participate in education programs (RKP Staff, 2011). The distances traveled from schools to the Park (straight-line distance on the map) range from 5,046 meters to 26,635 meters with an average of 17,077 meters. Most of the schools are located in the City of Calgary but there is also one from DeWinton and one from Town of Chestermere. The cost of bussing a school to and from RKP is about $200 (McColl, 2011).

3.5.5.3 Heritage

Heritage services are the opportunities and experiences related to traditional, historical, spiritual and religious understanding and uses of a place. These services refer to the 'place-based' benefits derived from beliefs, activities and experiences, such as stated 'sense of place', 'sense of belonging', and 'sense of self/identify'. For example, a heritage ES could be learning about cultural traditions, such as sweetgrass harvesting.

The stakeholders participating in a pilot workshop indicated that there was a sense of peace and wellbeing, as well as a sense of belonging and identity derived from the landscape in the study area. The landscape was also reported to be potentially inspiring to people. Activities undertaken for recreational and educational purposes, including hunting and artistic activities can also have correlations to heritage services. Further work is needed to better understand how wetlands across the study area contribute heritage ES to local people and to all Albertans.

3.5.5.4 Aesthetics

Aesthetic services refer to opportunities and experiences relating to the beauty of nature and its appreciation or enjoyment. The benefits that people derive from wetlands include opportunities for photography and artwork undertaken on the landscape, as well as a general appreciation of the landscape, surface waters and wildlife. Many people gain these benefits along with educational and recreational activities including hiking, hunting and wildlife viewing.

The pilot project specifically examined one aspect of an aesthetic service, the amenity value of wetlands associated with housing prices. Urban developments are increasingly incorporating wetland features into their landscape planning for two main reasons - amenity and aesthetics, and stormwater management. The importance of leaving natural areas in communities has been quantified previously. For example, Foley (2007) found that residents in Bridlewood Creek (a community in Southwest Calgary) were willing to pay more to live close to the local community wetland.

The ES pilot used a hedonic pricing analysis to determine how housing prices are affected by proximity to wetlands. Hedonic pricing analysis uses housing prices and distances to wetlands to determine the economic benefits from wetland proximity. Two residential developments were chosen for this assessment: McKenzie Towne and Copperfield, located in the southeast urban fringes of Calgary (*Figure* 13).

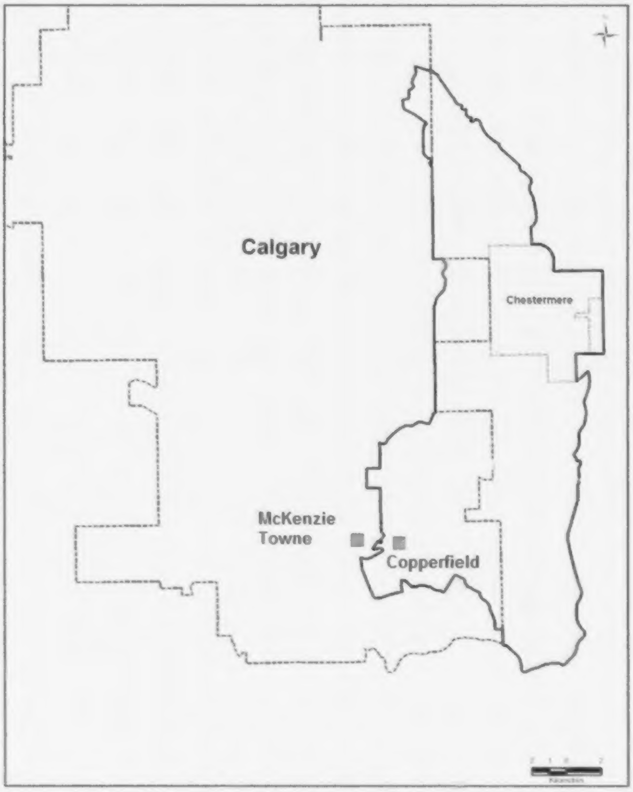


Figure 13. Study Communities: McKenzie Towne and Copperfield

In McKenzie Town there is clear relationship between property value and distance/adjacency to wetlands. If the property is adjacent to a wetland, the value of the house increases by **$5,136** over the mean house value in the development. Decreasing distance to the nearest wetland is directly related to increasing house values. For every additional 10 metres closer to a wetland, house values increase by $271.

For Copperfield, if the property is adjacent to a wetland, the value of the house increases by **$4,390** over the mean house value in the development. However, the impact of wetlands on housing price in terms of distance is not so straightforward. One possible explanation is that Copperfield has a dense distribution of wetlands, with four wetlands in the neighborhood. With most of properties (82 per cent) located within the distance of 200-450 metres from wetlands, there is lack of variability to demonstrate marginal values in the model.

For McKenzie Towne, it's reasonable to make the assumption that beyond a certain distance (for example, the 700 metre distance from wetlands to the farthest houses), house values may no longer be affected by the presence of wetlands. Based on this assumption, and holding all the other house features equal to their sample means, the total house values would decrease by **$2 million** if all the sales properties (390 properties) currently located within 700 metres of wetlands were relocated beyond 700 metres from wetlands. This represents 1.4 per cent decrease in house values. The value decrease becomes **$12 million** if all existing properties (2120 properties) within the 700 metres were moved out. This represents 1.5 per cent decrease in house values.

One limitation to hedonic price method is that it measures a subset of total benefits wetlands provide. In this study hedonic analysis measured only the amenity value of proximity to wetlands perceived by owner-occupied, single-family residence purchasers. Wetlands provide other benefits such as water quality improvement, groundwater recharge and recreation. The value of these benefits may not be fully perceived by residents, or the benefits provided are public goods. In the case of public goods, only part of the benefits will accrue to property owners, thus, hedonic property valuation is a subset of total value provided by wetlands.

3.6 Individual Wetland Site Assessments of Wetland Ecosystem Services

3.6.2 Introduction to WESPUS

The Wetland Ecosystem Services Protocol for the United States (WESPUS) was identified by Alberta Environment and Water as a **tool with the potential to help address identified gaps in the current regulatory context surrounding wetlands**. WESPUS is a rapid assessment site-level tool that scores a wetland's ability to provide multiple ES and scores the relative value of these ES to nearby populations. The purpose of the WESPUS component of the pilot study was to identify the potential applicability of WESPUS for assessing ES from wetlands in Alberta, and to provide a site-level assessment of ES in study area wetlands. Other objectives included the identification of potential limitations and required changes to the WESPUS protocol that would need to be made prior to more widespread application of such a method in the province.

WESPUS is intended for all of temperate North America and models over 16 ecosystem functions, including, among others:

- water storage and delay;
- sediment retention;
- phosphorus retention;
- nitrate removal;
- carbon sequestration;
- aquatic invertebrate habitat;
- amphibian and reptile habitat;
- waterbird feeding and nesting habitats;
- songbird, raptor, and mammal habitat;
- pollinator habitat; and
- native plant diversity.

WESPUS requires field visits to each site combined with desktop assessments to complete ratings for 140 criteria. Outputs of the WESPUS Excel spreadsheet include a number representing the relative effectiveness of each function, as well as the relative benefits for humans associated with each ecosystem function.

WESPUS output is divided into two categories – function and value. Function scores determine the capacity of the wetland to perform specific functions that may be desirable to humans. Value scores determine the relative benefits that humans actually get from specific functions. As an example, a wetland may have a high score for water storage and delay, but may have a low score for the value of this function if there are no populations nearby to benefit from the wetland's ability to control flooding.

3.6.3 Assessment sites

Figure 14 shows the location of the wetlands assessed using WESPUS. A total of 22 assessments were completed on 21 sites selected based on access, with the intention of assessing a variety of different wetland classes according to the S&K wetland classification system for prairie pothole wetlands.

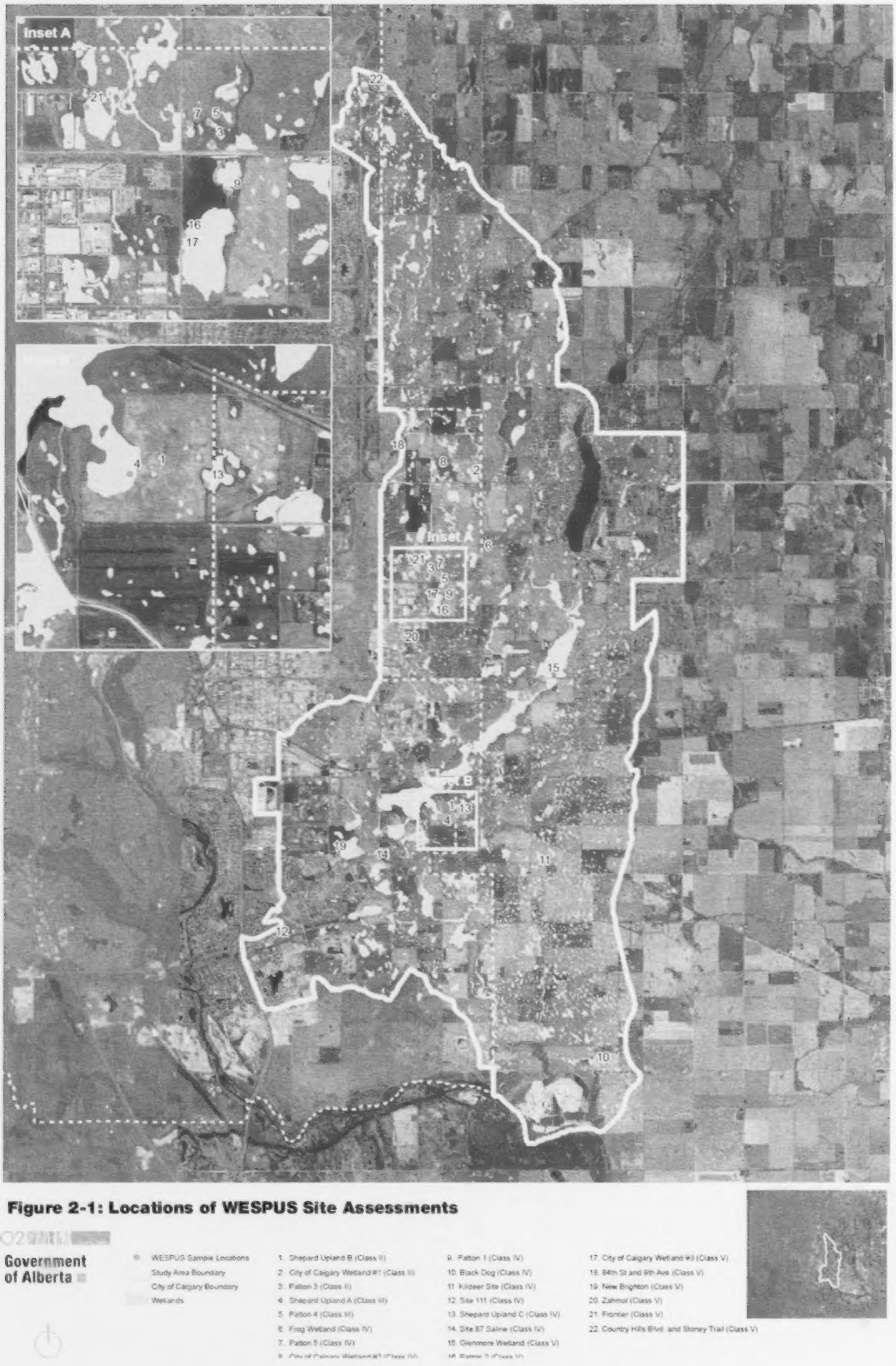


Figure 2-1: Locations of WESPUS Site Assessments

Inset A
Inset B
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Government of Alberta
WESPUS Sample Locations
Study Area Boundary
City of Calgary Boundary
Wetlands
1. Shepard Upland B (Class II)
2. City of Calgary Wetland #1 (Class II)
3. Patton 3 (Class II)
4. Shepard Upland A (Class III)
5. Patton 4 (Class III)
6. Frog Wetland (Class IV)
7. Patton 5 (Class IV)
8. City of Calgary Wetland #2 (Class IV)
9. Patton 1 (Class IV)
10. Black Dog (Class IV)
11. Killdeer Site (Class IV)
12. Site 111 (Class IV)
13. Shepard Upland C (Class IV)
14. Site 87 Saline (Class IV)
15. Glenmore Wetland (Class V)
16. Patton 2 (Class V)
17. City of Calgary Wetland #3 (Class V)
18. 84th St and 9th Ave (Class V)
19. New Brighton (Class V)
20. Zahmol (Class V)
21. Frontier (Class V)
22. Country Hills Blvd. and Stoney Trail (Class V)

Figure 14. WESPUS assessment sites within study area

3.6.4 Results from WESPUS assessments

Table 6 presents the scores for functions in each wetland assessed. *Table* 7 presents the scores for values associated with each wetland for humans. Below we summarize observations and important points related to the use of WESPUS as a tool for rapid assessment of ES in Alberta.

- Results were analyzed to see whether scores are associated with wetland class. It was found that mean values for each S&K class should be interpreted with caution, as the observed variability within each wetland class is relatively large, and the sample size within each class is very low. It is recommended to complete more sample sites if the desired outcome is a "look-up" table for the functions and values of each particular S&K wetlands class.
- The results match with the fact that all wetlands assessed are prairie pothole wetlands, bogs and fens might have to be assessed using further criteria.
- Since this is a "rapid" assessment and all values generated are relative, there are no absolute values placed on the functions themselves (i.e., kilograms of carbon sequestered, cubic metres of water stored). As a result, comparing values across different wetlands must be done with extreme caution. For example, a value score of 4 for wetland A and 2 for wetland B does not mean that wetland A has double the value of wetland B.
- All wetlands in the region seem to perform fairly well for water quality and aquatic habitat support functions.
- Apart from Class II wetlands, most wetlands in the study area provide high hydrologic functions related to water storage and delay. The Class II wetlands, which are temporary in nature and have limited water storage capacities, would also be expected to have much lower overall hydrologic functions per wetland.
- Wetlands in all S&K classes provide fairly high aquatic habitat support functions; this is consistent with the reputation of prairie pothole wetlands as the "duck factory of North America", as well as research indicating that heterogeneity of wetland types is important for maintaining biodiversity (Weller 1978; Gilbert *et al.*, 2006).
- It is interesting to note that four of the seven Class V wetlands sampled have been constructed for compensation and it may be helpful to identify the differences in effectiveness and values based on their designated purpose.

Table 6. Grouped wetland functions and their relative effectiveness across sites.

Stewart and Kantrud (1971) Wetland Class	II	II	II	III	III	IV	IV	IV	IV	IV	IV	IV	IV	IV	V	V	V	V	V	V	V	V
Site Name	Shepard Upland B	City Wetland #1	Patton 3	Shepard Upland A	Patton 4	Frog Wetland	Patton 5	City Wetland #2	Patton 1	Black Dog	Kildeer Site	Site 111	Shepard Upland C	Site87 Saline	Glenmore Wetland	Patton 2	City Wetland #3	84St&9 AveSE	New Brighton	Zahmol	Frontier	CountryHills & Stoney
Hydrologic Function (WS)	0.36	0.33	0.33	5.00	7.00	3.25	3.25	7.00	5.75	4.50	3.69	2.33	7.00	4.75	3.38	3.26	6.00	3.51	3.14	8.00	3.25	3.85
Water Quality Group (WQ)	3.44	9.72	9.38	10.00	10.00	10.00	10.00	10.00	10.00	10.00	6.43	7.83	10.00	10.00	7.40	7.70	10.00	6.08	7.55	10.00	10.00	8.07
Carbon Sequestration (CS)	0.51	2.00	2.50	1.61	1.32	2.22	1.70	1.81	1.65	1.67	1.68	2.57	1.38	2.44	2.19	1.97	1.72	2.12	1.57	1.20	1.68	2.06
Fish Support Group (FISH)	4.05	1.92	0.83	0.38	0.73	3.80	3.72	1.58	2.84	2.30	3.42	4.84	3.69	0.00	3.16	3.05	4.59	3.93	2.91	3.33	3.23	3.87
Aquatic Support Group (AQ)	6.92	8.72	7.25	8.04	6.93	7.58	7.07	7.63	7.56	7.58	7.91	6.91	7.74	7.37	6.90	7.37	7.64	6.47	5.56	6.65	7.01	6.41
Terrestrial Support Group (TERR)	3.72	7.58	4.50	6.38	5.40	4.79	6.00	-	5.20	6.08	6.90	5.13	5.43	5.94	4.61	5.20	5.18	4.32	4.73	5.08	4.75	3.41
Public Use & Recognition (PU)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Provisioning Services (PS)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 7. Grouped wetland functions and their relative values to humans across sites.

Stewart and Kantrud (1971) Wetland Class	II	II	II	III	III	IV	IV	IV	IV	IV	IV	IV	IV	IV	V	V	V	V	V	V	V	V
Site Name	Shepard Upland B	City Wetland #1	Patton 3	Shepard Upland A	Patton 4	Frog Wetland	Patton 5	City Wetland #2	Patton 1	Black Dog	Kildeer Site	Site 111	Shepard Upland C	Site87 Saline	Glenmore Wetland	Patton 2	City Wetland #3	84St&9 AveSE	New Brighton	Zahmol	Frontier	CountryHills & Stoney
Hydrologic Function (WS)	1.25	2.08	3.00	2.58	3.00	2.63	3.00	2.58	2.63	2.33	2.08	4.33	3.17	2.92	2.42	3.00	2.63	3.33	3.33	3.08	4.08	3.58
Water Quality Group (WQ)	1.93	4.23	6.13	3.73	6.13	5.46	6.13	4.96	5.71	6.33	5.33	5.43	5.64	5.15	4.69	5.50	5.21	5.35	3.33	4.96	6.46	4.78
Carbon Sequestration (CS)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fish Support Group (FISH)	3.94	6.42	7.25	10.00	6.07	6.78	6.74	3.32	6.60	6.52	7.88	5.11	6.80	7.37	5.94	5.75	6.74	5.91	5.56	10.00	10.00	5.10
Aquatic Support Group (AQ)	6.67	5.50	5.33	10.00	5.33	8.67	5.33	8.00	8.67	5.33	5.33	9.33	8.67	9.33	8.67	5.33	8.67	5.33	2.00	10.00	10.00	5.50
Terrestrial Support Group (TERR)	6.67	5.83	8.00	10.00	8.00	8.00	8.00	-	8.00	8.00	8.00	9.00	8.00	9.00	8.00	8.00	8.00	8.00	3.06	10.00	10.00	5.50
Public Use & Recognition (PU)	10.00	2.67	4.17	10.00	3.33	3.33	6.04	2.22	4.17	5.83	5.83	10.0	2.22	4.76	2.33	3.33	2.67	3.33	4.76	7.62	7.22	2.62
Provisioning Services (PS)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WESPUS outputs can also be prepared in an illustrative format. Flower diagrams (*Figure* 15) for the ecological indices, by site, and the other show both the function and the value of different ES for each site. Every 'petal' on the flower represents the score for that particular ES (the longer the petal, the higher the score).

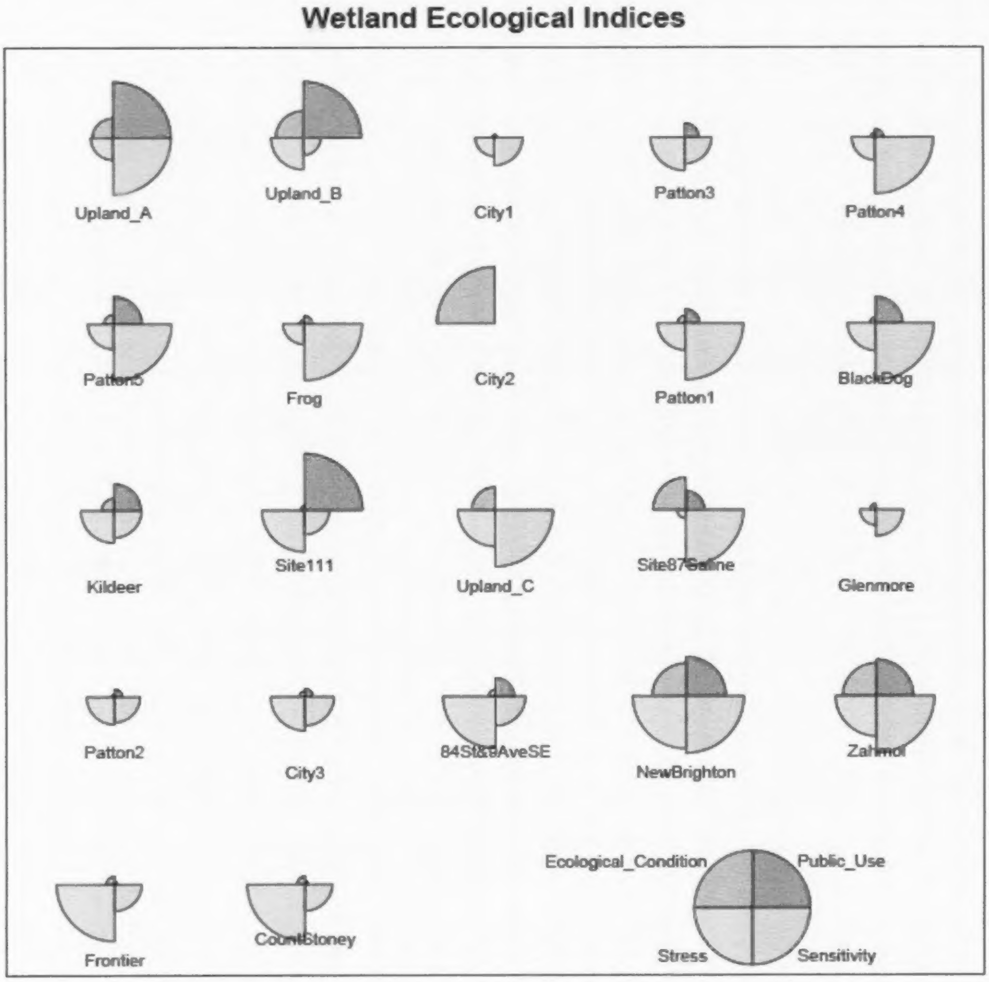


Figure 15. WESPUS output sample – flower diagrams

4.0 Discussion

The ES pilot attempted to achieve three objectives, one of which involved assessing ES in the study area to help fill three identified gaps in the wetland approval process (see Section 1). This section provides a discussion of how the assessment results presented in Section 3 inform these three information gaps, and more generally, how the pilot was able (or not) to achieve the three objectives and meet the overall pilot outcome. Where relevant, this section also includes a number of learnings that contribute to an understanding of how to operationalize an ES approach in Alberta.

The discussion is organized in the following sections:

4.1 Support current wetland management by meeting the information needs of wetland approvals decision makers;

(Focus on how the ES pilot informed the three information gaps identified by wetland approvals decision makers)

4.2 Building an approach to support decision making by explicitly demonstrating the trade-offs between development and ES benefits provided by wetlands; and

4.3 Identifying data and capacity gaps for assessing ES for future focus.

The section concludes with a brief discussion of how the pilot achieved the overarching anticipated project outcome (4.4).

4.1 Support current wetland management by meeting the information needs of wetland approvals decision makers

Wetland approvals decision makers were involved in the assessment process from the initial stages of the pilot and provided continuous guidance on what information could assist them in making more informed wetland approvals decisions in the context of increasing development pressures. Some of the information desired was straightforward to gather (e.g., what ES are important in the area, how many wetlands are there and their distribution), while some was beyond the scope of the ES pilot (e.g., consistent temporal and spatial quantitative data for all ES integrated on a single map). In some cases, the ES pilot team lacked available data or capacity to provide complete answers. However, the information generated by the ES pilot provides a baseline of knowledge about wetland ES in the study area that decision makers can apply in wetland approvals decisions.

In interviewing the three decision makers in October, 2011, there was consensus that the ES pilot met their expectations. While each decision maker noted that the results have limitations, the results resonated with them by providing useful new information and meaningful data to use in their approvals processes. One decision maker commented that (the ES approach) “is another useful tool in the tool box”. This results report will inform a ‘Summary for Decision makers’ report that is intended to present the results and findings to specifically make it usable for their decision making processes.

In this section, we discuss how the ES assessment results contribute to the three prioritized information gaps in the wetland approvals process that were identified by decision makers.

GAP 1: There is insufficient evidence to support avoidance, minimization and compensation decisions on wetlands.

The ES pilot identified the ES that are most important to people living in the study area, expanding understanding of how wetlands benefit people in the study area. Identifying the majority of ES provided by wetlands, and how they are valued by people can help decision makers identify priorities for avoidance, minimization and compensation decisions for individual wetlands and plan wetland management at larger landscape scales. Decision makers remarked throughout the ES pilot process that new information about wetland ES armed them with a broader awareness and understanding of the functions, services and benefits wetlands provide to people.

Many of the wetland functions, ES, benefits and values introduced in the ES pilot are missing in current municipal Biophysical Impact Assessment/Wetland Impact Assessments (BIA/ WIAs). In the current process, generally, the more disturbed the wetland, the less value it has in has; however the ES pilot demonstrates that although a wetland is degraded, it could be high functioning and provide a number of ES and benefits. This information could inform trade-offs and also help to highlight hot spot areas to avoid in the planning process.

The ES pilot incorporated socio-cultural information on how people value different ES in the study area. Information about local people's perceptions of why wetlands are important can directly inform wetland approval decisions, as this is new information about the value of wetlands to society. Studies conducted for the pilot demonstrate that even the most abstract cultural benefits (e.g., heritage benefits) are consistently rated as of 'high' or 'medium' importance to people. In one ranking study, individuals ranked 'aesthetic' benefits second only to water quality, exceeding the importance they assigned to flood control, water supply, recreational benefits and other benefits. Thus, decisions about wetlands can consider conservation issues, the economic benefits associated with wetlands (e.g., avoided costs of flood mitigation), but also how societies value wetlands in a broader sense.

The ES pilot drew attention to the fact that wetlands provide multiple ES simultaneously, which is important when considering avoidance or compensation options for wetlands. The benefits from natural wetlands generally far exceed the benefits provided by constructed wetlands when all ES are considered together, as constructed wetlands are often managed for only one or two functions (i.e., usually water storage and flood control). The ES pilot included the multiple cultural ES provided by wetlands that are often not considered in decisions. While the assessment identified multiple ES from wetlands, it did not provide a quantitative analysis of the multiple ES provided by wetlands across the study area and how they are jointly produced. However, the site assessment tool WESPUS was tested by the ES pilot and does provide a way to examine the multiple ES provided by individual wetlands.

While it is unclear whether the information on conditions and trends of ES developed in the ES pilot is sufficient or specific enough to directly inform wetland approval decisions, we expect that baseline information on multiple ES will be valuable for building knowledge of ES in the study area. The information developed by the ES pilot provides a better understanding of how ES are produced and how their condition has changed over time in the study area, and provides a platform from which to build further understanding of ES at local and regional scales.

It is clear from ES pilot results that both regional and local scale understanding of ES is important for the management of wetlands. For example, the provision of flood control and water purification services relies on wetlands acting together at the watershed scale. For these two ES, the position of a wetland on the landscape and its connection to other wetlands contributes to quality of function and delivery of services. These findings suggest that regional wetland management and planning is crucial to maintaining or improving ES across the landscape, and as such, wetland approval writers should consider incorporating aspects of landscape level assessments in the approval process. Site-scale assessments alone will not be sufficient to inform effective management of these ES.

The ES pilot tested a site assessment tool for ES called WESPUS, or the Wetland Ecosystem Services Protocol for the United States, that can help wetland approval decision makers develop information about the ES provided by individual wetlands. Decisions related to avoidance, mitigation and compensation for wetlands are generally made on a wetland-by-wetland basis. WESPUS is a rapid assessment tool that scores multiple wetland functions and their value to human well-being. It can also provide objective information on the values and functions of small and temporary wetlands that are often dismissed as unimportant when compared to large and visually appealing wetlands with permanent open water zones. Class I and II wetlands, for example, may still have a relatively high capacity to perform water quality improvement services and support aquatic habitat.

WESPUS provides a tool, similar to the pilot's ES approach, to shape the process of avoidance, mitigation and compensation in a manner that may better reflect public values associated with wetlands. If a wetland approval writer does not select avoidance or minimization, approval writers could use this tool to determine appropriate compensation and restoration requirements. Using this 'full cost accounting' approach that considers multiple ES provided by wetlands could improve ecological and socio-cultural outcomes of compensation and restoration decisions. For example, current compensation decisions are based on area (i.e., an impact of one acre requires a replacement of three acres); whereas ES assessments can identify the function and benefits of the wetland that will be impacted, and decision makers can identify a restoration project that results in equivalent functions and benefits. Understanding the functions and values associated with individual wetlands might also provide incentives to developers to incorporate the wetlands into the development setting. In some cases this could produce additional economic benefits such as enhanced property values from enhanced scenic quality or reduced infrastructure costs (e.g., stormwater ponds).

WESPUS is currently being evaluated for further application in Alberta as modifications are required to make it more contextually relevant. It is anticipated that the tool could be applied at the site scale to understand the function and values of a wetland, but also at larger scales if a GIS-based regional version is developed. A regional version of the model could be used to understand ES that are produced at the watershed scale (e.g., flood protection and water purification) and could be used to evaluate the cumulative impacts of landscape change on wetland ES. A version of WESPUS that is tested and refined for the Alberta context could allow for the reliable identification of wetlands that are crucial for the provision of individual or multiple ES considered to be highly valuable within a specific context. This tool would be important for identifying instances where wetland removal should be avoided.

In addition to WESPUS, other methods from the ES pilot could be used to expand the current wetland approval process. For example, wetland approval writers could initiate a trial to require ES assessments that include an analysis of ES beneficiaries to complement existing requirements for BIA/WIAs. This would allow for the consideration of all of the ES from wetlands and how they benefit different individuals, communities and businesses that would be affected by wetland approval decisions. An analysis of ES and their links to beneficiaries could be required in the development proponents' application and residential sub-division design, enabling win-win development – residential subdivisions that are designed in line with the values and needs of local people. For example, if certain areas are highly valued for bird watching or aesthetic landscape qualities, development could be designed to complement these existing landscape uses.

GAP 2: There is insufficient consideration of cumulative effects and long-term consequences of decision making.

Historical trends assessed for the three of four[16] ES examined show that the loss of wetlands over time has led to a substantial cumulative loss of all of these services. The pilot decision makers stressed the importance of providing current information on the state of wetlands in the case study area, but also that trend analyses were important for understanding the implications of previous development decisions on wetlands and their ES and helping to link current decisions to long term consequences. *Figure* 6 provides a snapshot of the changes in distribution and abundance of wetlands in the case study area, providing a simple tool to inform discussions on cumulative effects.

Trend assessments in the ES pilot relied on wetland inventories created for different periods of time between the 1960s and 2010. Simple models were applied to these inventories to estimate the potential of wetlands to provide different ES. The resulting information will provide a baseline for understanding how wetland ES have been lost over time. However, further work is needed to better understand the cumulative effects on ES of wetland removal, including more accurate and consistent wetland inventories for these and additional time periods, and the development and assessment of indicators to provide information about how changes in wetlands are actually impacting the benefits that people get from wetlands. In other words, a more developed flood control assessment would provide information on where flood risk is increasing and why to complement the completed assessment of wetland potential to deliver flood control services.

Developing and delivering a cumulative effects management system (CEMS) is one of AEW's main priorities, and the ES pilot demonstrates that an ES assessment is an approach to informing about the cumulative effects (CE) of decisions on the landscape, which can inform CEMS outcomes and management decisions. Stakeholder engagement was used in the ES pilot to understand how ES are important to people in the case study area. The discussion of historical changes in wetlands and how changes have affected the delivery of benefits from ES can help focus management plans on issues of relevance to local people. Stakeholders were particularly interested in cultural ES, as well as hydrological ES such as flood control and water storage; however, ES provision is interrelated and management plans need to determine the functions and assets needed to provide multiple ES in a sustainable manner. The development of 'cascade' diagrams linking ecosystem assets, functions, services and benefits for each of the pilot ES will help to strategically identify the components of the landscape that need to be monitored and managed for long-term provision of ES that matter to people.

---

[16] Historical trend analysis was not possible for flood control due to data limitations.

An important assessment finding related to CE is that many ES are not produced by individual wetlands, but rather by wetland complexes, landscapes and watersheds. For example, flood control and water purification are most effectively provided by many wetlands distributed across a landscape. In addition, wetlands in some positions within a watershed can provide more effective flood control than wetlands in other positions. How ES are produced and at what scale are important considerations for understanding how changes in the ability of landscapes to produce ES can accumulate over time.

Complementarily, socio-cultural research conducted within the ES pilot demonstrated that some benefits from wetlands are not provided by individual wetlands, but from several wetlands as components of a larger landscape. Recreational services such as opportunities for hiking and viewing wildlife, and services associated with heritage and aesthetic qualities of landscapes, can be provided by a single wetland, but these services are more attractive when provided by complex landscapes that incorporate an abundance of wetlands of different types and sizes. The long-term consequences for cultural benefits are greater than the loss of individual wetlands, and are not directly compensated for by another wetland restored or protected elsewhere. Thus what we know of cultural benefits also suggests that impacts to benefits would be best considered in a context of cumulative and long-term consequences.

The application of WESPUS as information to inform cumulative effects is unclear at this time. Data from WESPUS site assessments can contribute to inventories of wetlands and the services they provide within a particular watershed. However, the values generated by WESPUS are relative and not necessarily spatially explicit (e.g., total area of wetlands is not factored in to WESPUS). This may lead to some ambiguity and criticism regarding whether WESPUS actually does address cumulative effects properly or not. Applying WESPUS in the context of individual applications for wetland disturbance would improve cumulative effects management over time by moving towards greater maintenance of wetland functions and services as opposed to focusing on maintaining wetland acreage under a 'no further loss' policy. Further research and investigation is required to determine how to make WESPUS compatible with a cumulative effects management system.

The ES pilot is a first step towards building knowledge about ES in the study area and in Alberta, and provides initial understanding of how ES information might inform cumulative effects considerations. *Table* 8 presents some specific learnings from our ES pilot results that are relevant to assessing and understanding cumulative effects related to ES.

Table 8: ES results and cumulative effects

ES	Relevance for cumulative effects	Relevance for long-term management
Water storage	-Large number of small wetlands results in abundant water storage on landscape	-Removal of small wetlands over time leads to an important loss of water storage on landscape -Water storage supports all other wetland ES
Flood control	-Flood control capacity provided by individual wetlands is determined as much by location of the wetland on landscape as by the size of wetland	-Regional planning for development is needed to determine which wetlands are most crucial to flood control services
Water purification	-water purification occurs at the watershed scale, and a large number of distributed wetlands most effectively provide this ES -disturbance thresholds exist beyond which wetlands can no longer provide this ES	-As more land use activity occurs, the filtering capacity of wetlands becomes more valuable to ensure connected water is of good quality for residential, agricultural and industrial use. -Conversely, as more land use activity occurs, wetlands can become overloaded and function less well as water purifiers
Carbon storage	-Wetlands of differing sizes and categories store carbon	-As Alberta develops carbon protocols for the carbon offset system, the ability of wetlands of all sizes to store carbon will contribute to the provincial climate change goals -Incentives to manage for carbon storage are needed as the benefits are not always recognized at local scales
Cultural ES	-Wetlands and wetland complexes provide multiple cultural benefits that are highly values by stakeholders	-Long term consequences for cultural benefits are greater than the loss of individual wetlands, and are not directly compensated for the creation of another wetland in another location

GAP 3: There is limited ability to communicate the 'values' of wetlands.

The ES pilot revealed the benefits associated with individual ES and the role that ES can play in contributing to quality of life for southern Albertans. A request from the pilot decision makers was to demonstrate biophysical, economic and socio-cultural values associated with wetlands in order to inform trade-off decisions. The ES pilot provided biophysical information on the value of wetlands of all sizes and in different positions within study area landscapes in relation to the provision of multiple ES. Pilot results also provided monetary estimates of the economic value of wetlands in the study area in relation to the provision of multiple ES. Socio-cultural assessment results showed that people place high value on multiple ES provided by wetlands. Finally, the site assessment tool WESPUS quantified the benefits to humans of multiple ES that are provided by individual wetlands. These results provide rich information to decision makers on the value of wetlands from multiple perspectives. Many of the ES values that were determined were previously either not quantified or unrecognized in the current determination of 'wetland values' in the approvals decisions.

ES pilot results demonstrated that all classes of wetlands in the case study of area contribute benefits, regardless of size and magnitude of current degradation. Even small wetlands provide essential services such as water purification and flood control, sometimes in conjunction with adjacent and connected wetlands. WESPUS site assessments demonstrated that different types and sizes of wetlands provide multiple ES. This means that the net benefits to humans from natural wetlands are higher than the benefits associated with constructed wetlands designed to provide a single service such as flood control. With this information, decision makers can compare the benefits from engineered and ecological management solutions to ES degradation. Stormwater retention ponds generally provide few services, whereas intact wetlands of all classes and sizes contribute multiple functions and benefits. Where constructed wetlands are necessary, management for multiple ES could be a goal.

WESPUS will be invaluable in assessing and communicating the value of individual wetlands. A standardized protocol such as WESPUS allows for a quantifiable and objective approach to valuing the benefits of wetlands for individuals and communities. Further WESPUS assessments could be conducted to provide more defensible evidence of the value of leaving natural wetlands intact, or of engineering wetlands that mimic natural wetlands more closely. For example, WESPUS can be used to evaluate the ES from engineered wetlands and compare the results to those from natural wetlands. Preliminary testing of WESPUS showed that the constructed wetlands that were assessed in the pilot had lower ES values than the natural wetlands that were assessed.

The ES pilot provided an opportunity to test emerging valuation methodologies for economic values associated with ES. One of the criticisms of some of the work in the environment sector is that it excludes or has not developed an appropriate mechanism to integrate economic and cultural information. For instance, without knowledge of the value wetlands have to people and communities, there are few disincentives to keep landowners from draining or infilling rural wetlands. While the economic valuation methods were limited by a lack of suitable or locally-specific data, the conservatively estimated dollar values estimated for ES are illustrative of the generally high economic contributions of wetlands.

An important goal for future ES work will be to provide economic information on the specific contributions of wetlands to development projects. For example, residential developments depend on flood control (no matter how it is provided) and can be more economically valuable if there are multiple cultural ES provided nearby. Compelling information for wetland approval decisions would include estimates of cost-savings and other economic benefits provided by intact wetlands to subdivision developers. For instance, it may be meaningful to developers to understand the values and benefit of the wetlands that may be lost with certain applications. Understanding the costs of removing wetlands, the breadth of lost or degraded ES and the cost to engineer stormwater ponds may provide some motivation to look at the maintenance and potential enhancement of wetlands. Municipalities in the study area are dealing with significant flood issues. The Shepard Regional Drainage Plan is developing solutions that may be informed by the methods and information from the ES pilot from the Flood Control and Wet Areas Mapping results.

Cultural services, such as aesthetic appreciation of the landscape and opportunities for recreation and education, were found to be highly important to stakeholders in the study area. Cultural services are challenging to assess and 'value' and have not been systematically considered in wetland approval decisions. Pilot results showed that study area residents are positive about the educational, recreational, heritage and aesthetic services from wetlands, and that positive attitudes are similar across gender, age and occupational categories. So although some cultural services are often non-material and even quite abstract, people still consider them important and comparable to services such as flood control and water purification. These results show that cultural services may warrant increased consideration when planning for wetland management.

Table 9 presents information gathered in workshops and from surveys on who benefits from wetland ES and how these ES are valued.

Table 9 Beneficiaries and ES value examples

Ecosystem Service	Beneficiaries of ES	Examples of value of ES
Water storage	Farmers, downstream groups, municipalities, agriculture	Water consumed for stock watering, water supporting other ES that benefit people directly
Flood control	Home owners, farmers, industry, municipalities, developers	Feeling of safety, reduction in insurance and municipal infrastructure costs, reduced investment risks
Water purification	Farmers, downstream groups	Improved water quality for recreation, stock watering and crop application, reduced costs of water treatment
Carbon storage	Albertans, Canadians and Global Society	Localized climate moderation, feeling of contributing to climate change issue, financial compensation for offsets
Cultural ES	Individuals, Cultural, science, and academic groups, non-residents	Aesthetic appreciation, recreation, schools and individuals science and learning, hiking and wildlife viewing

4.2 Building an approach to support decision making by explicitly demonstrating the trade-offs between development and ES benefits provided by wetlands

The ES pilot was experimental and exploratory. It provided new information and tested numerous approaches for assessing and understanding ES in Alberta. The pilot attempted to build understanding of the interdependencies that exist between development decisions and wetland ecosystems.

As guided by Ash *et al*., (2010), "the three fundamental qualities of a sound assessment are relevance, credibility and legitimacy". These core values were developed through the participatory nature of the ES pilot. It was highly collaborative, involving stakeholders from multiple provincial departments, Rocky View County, the City of Calgary and a variety of non-profit organizations, business and research institutions.

Capacity building was also at the core of the pilot. Working groups were developed and the dual stream of assessment activities and learning sessions were designed to build shared understanding of ES, the ES approach and potential assessment methodologies for achieving the project outcome and related objectives.

The results of the pilot assessment and process demonstrate that meaningful ES information can be generated to support trade-off decisions and to expose ES benefits in the planning and approvals stages for wetlands. Much more work is needed to develop methods and databases that can be used to analyze ES at different scales and answer specific questions related to ES management. However, target decision makers expressed that the results are useful for their decisions processes; from the WESPUS rapid assessment tool, to the quantitative findings on ES condition and trends, to the qualitative understanding of the importance of ES to local people and organizations. This provides evidence to support the value in further developing and operationalizing the ES approach for Alberta.

The ES pilot described linkages between the ES provided by wetlands and their contribution to human well-being or quality of life. Maintaining healthy ecosystems translates into more 'free' services to support Alberta's competitive advantage, such as clean water, rich soil, fresh air and raw materials. An ES approach connects development activities to their dependence on the environment, and explicitly tried to determine what economic activities a healthy environment can support, now and into the future. This information benefited the pilot decision makers but also Steering Committee and Review Panel members, as well as additional stakeholders that were involved during various aspects of the project, further expanding the knowledge base in Alberta and across Canada.

The ES approach can be operationalized for Alberta; however, there are a number of considerations for future applications and iterations of the approach. While the Lessons Learned and Technical Report will provide more details to respond to Objective 2, the following are some key learnings from the Results Report to contribute to this objective:

- Ecosystem service benefits are context specific, as they relate as much to how the environment is used and valued as to how services are produced by ecological processes. Understanding and designing an ES approach for the place-based context for the issue is critical.

- ES are produced at different scales, both temporal and geographic, and people benefit from ES at different scales. This scale mismatch is important to consider so the ES approach can be designed at a scale that will be relevant to decision makers and ES beneficiaries.

- Building credibility, legitimacy and policy relevance is necessary to ensure that results generated are useful and believable. In this pilot, more than ES and issue experts were brought together to ensure that the ES approach was developed and carried out in a credible manner.

Another area to be addressed in future work is around the role of biodiversity. A number of team members and stakeholders were concerned that biodiversity appeared to be absent from the ES approach and results. In discussions with international experts, it appears that there is no one accepted framework to bring ES and biodiversity together. For the purposes of the pilot, biodiversity underpins the supply of ES; however that was not acceptable to all members. This also led to some disagreements on some of the benefits not listed, such as wildlife habitat.

4.3 Identifying data and capacity gaps for ES assessment

The ES pilot forwarded understanding of the services that wetlands provide and how they contribute to the well-being of Albertans. However, there is a lack of capacity in using and implementing the ES approach in Alberta and there are a number of knowledge and process gaps that were identified during the pilot.

The capacity required to master the implementations of an ES approach is quite unique and rare. There are few people globally who have undertaken ES assessments at the scale and scope undertaken in the pilot. An interdisciplinary approach is required to contend with the complexity of ecosystems and how they interact with socio-economic systems. Interdisciplinary work is extremely difficult due to a lack of shared language, and collaboration on ecosystem service work is particularly challenging due to this type of science being relatively new. A consequence of this was that team members were often unsure about what information was needed, what to ask for and what level of uncertainty existed in the information that was collected or in results produced. Outside experts were brought in as much as possible to help with these issues.

Beyond understanding the questions to ask, much of the information and data that was recognized as necessary was often difficult or time intensive to obtain. For instance, a data sharing agreement was needed to access reports from the City of Calgary, Rocky View County and Town of Chestermere projects. This is an interesting issue as all the players collaborated very well together but systems and sharing agreements made the transfer of data difficult. It was essential to have a GIS team member to help negotiate these data needs and to interpret what team members needed from the datasets.

In future assessments, a completion inventory of data availability, supported by more active involvement between data owners to contribute suggestions for how the data can be incorporated is recommended. A gap identified as the project was coming to a conclusion was the lack of incorporation of wet areas mapping. Wet areas mapping (WAM) is a modeling technique used by Alberta Sustainable Resource Development primarily to assist Alberta's forest sector in ensuring the sustainability of these sensitive aquatic habitats that are threatened by the Mountain Pine Beetle. The data informs the user about hydrological risks on landscapes by identifying areas which are wet and susceptible to soil disturbance. It was recommended that the WAM may provide a useful data layer for the ES pilot but it was not incorporated due to time constraints.

Another gap in capacity was a lack of recognition of the time and resources required to complete the assessment. The ES pilot was limited by a lack of access to people due to conflicting commitments, resource constraints and difficulty finding all the skills sets needed, particularly people with biophysical and socio-cultural expertise. The time needed to complete each step in the ES approach was also underestimated, including all the activities required to conduct the various aspects of the biophysical, economic and socio-cultural teams. Integration of the various assessment activities would have improved the final assessment compilation; the project team recognized this challenge through the process and attempted to conduct activities and joint working sessions to create alignment in the results. Further improvement in this area is necessary.

There is more work that can be done to improve understanding of ecosystem service science from ecological, economic and socio-cultural perspectives. The Evaluation

Report and Technical Reports for the Economic and Socio-cultural sub teams will provide a more comprehensive response for Objective Three.

4.4 Meeting the Outcome

The overarching desired outcome for the pilot was *"the development and operationalization of the Alberta ES approach to provide a tool to enhance decision making."*

The pilot was successful in taking the experience and learning from the early ES application for the SAL and SSRP and developing a more robust assessment process to develop ES results. Building on the high level ES approach, the pilot team developed and applied a place-based assessment method on the current wetlands regulatory approvals process. The results of the pilot have provided new information to fill in assessed information gaps for decision makers, enhancing their ability to make decisions. Building on earlier ES work in the department, both qualitative and quantitative information developed by biophysical, socio-cultural and socio-economic assessment teams was developed.

In looking at the operationalization of an ES approach it can be said that the pilot has provided a guide for how to conduct an ES approach. Due to the novel nature of the work and issues of capacity and data availability, the process can be time intensive and expensive; therefore it would be wise to ensure that there are criteria when picking a next application. It would need to be of a scale and priority to warrant the resource expense and/or would need to be part of an overall commitment to use an ES approach more widely.

Overall the ES pilot made progress on the outcome; however hindsight helps us to understand that each application of an ES approach will be unique. The best approach may not be to develop a prescriptive and step-based approach for replication in other contexts. The geographic and decision contexts are key to determining what components of an ES approach will be most useful to apply. The ES approach report will provide more information on how a well-defined, but flexible set of assessment activities could be the best way to operationalize an ES approach within AEW.

The results and findings of the ES pilot provide both an opportunity to use the processes, methods and results to inform current wetlands approval decisions and opportunities to further develop capacity and understanding on how to do ES assessments and use the results to inform decision making.

5.0 Conclusions, Recommendations and Next Steps

As discussed throughout this report, ES are the benefits that nature provides to people. Ecosystems provide a multitude of resources and benefits, and decision makers increasingly require more sophisticated information to effectively manage human impacts on the landscape; the incorporation of ES into development decisions can be an input towards this end. The ES pilot focused on assessing the benefits that people get from wetlands in a quantifiable and comparable way to enhance the information currently used in wetland approvals decisions in southern Alberta.

While Section 4 synthesized the results of the ES pilot and explored how well the project achieved objectives, this Section presents the ES pilot in the context of other provincial initiatives, offering a number of concise conclusions and recommendations categorized by themes that emerged during the pilot process. These themes include: the AEW ES road map, cumulative effects management, the development of a wetland policy for Alberta, and the Land-use Framework and regional plans. The section will end with some of the immediate and medium term 'next steps' for the ES program for Alberta Environment and Water and the Government of Alberta.

5.1 ES Road Map

The ES pilot was launched to contribute to the AEW ES road map, an initiative to support the integration and adoption of ES into department policies, programs and strategies. The pilot contributes to the short term goal of the road map: enhanced appreciation and understanding of an ES approach to supporting policy, planning, and decision making is identified and supported by all levels of relevant management in AEW. The pilot has not only enhanced awareness, but also built capacity in AEW and the Government of Alberta more broadly through the collaborative and engaging processes incorporated throughout the project.

The ES pilot also contributed to the medium-term goal of the ES road map: the importance of ES is better understood and the department has increased its capacity for quantitative measurement of ES on the landscape to support policy, planning, and decision making within AEW. The pilot demonstrated that an ES approach can provide a systematic way to assess ES benefits and impacts, and can be used to explore the trade-offs associated with development decisions. The process, including routine 'lessons learned' activities, also provided the opportunity to test and provide further refinements to the Alberta ES approach (see *Figure* 1), further contributing to longer term goals of the ES road map.

Given the novelty of the assessment activities, a number of recommendations have emerged to further advance the ES road map:

- There is a strong need to examine how the local and regional assessment tools applied can be streamlined to improve efficiency and cost effectiveness. Many assessment activities occurred in isolation, and while the pilot team made efforts to integrate activities and align results, it is recognized that the pilot fell short of the intention to conduct a holistic and integrated ES assessment. Improved integration during the design phase can improve project delivery, communication and the final products, which can reduce costs.

- The data, information and resources used to complete ES assessments, particularly the biophysical analyses, was significant (e.g., LiDAR data for the study area alone was approximately $18,000.00[17]). It will be important to assess what scale and level of importance a policy or plan is to warrant the monetary and staff costs of conducting an ES assessment. Additionally it is critical to assess the support for the ES approach and the level of technical capacity available for biophysical, economic, and socio-cultural analyses, as well as capacity for project evaluation, communication, GIS and project management. Focusing on these important considerations will help to ensure that the ES approach builds on the highest government priorities, such as regional planning.
- The uptake of WESPUS is a 'low hanging fruit' to integrate ES into the wetland approvals process and other Government of Alberta activities as other ES assessment methodologies mature. With thirty years of testing and refinement already, the WESPUS approach requires minor modifications for the Alberta context. Given the popularity of WESPUS, it will be essential to build on the momentum generated in this pilot. It is imperative that guidelines are developed on how WESPUS is to be carried out in Alberta, including the credible resources and combination of technical skills necessary to conduct the assessments. The continued involvement of the WESPUS creator, Dr. Paul Adamus, combined with collaboration with other initiatives and researchers in the province will help address the recommended modifications and concerns raised to ensure that this useful tool is implemented effectively in the Alberta context in the near term.

5.2 Cumulative Effects Management

Cumulative effects and the CEMs designed for Alberta involve building broad and more holistic understanding of environmental impacts, thresholds and benefits from ecosystems to support a thriving economy. An ES approach can support cumulative effects management by informing on the potential cumulative effects of development decisions, and providing, for example:

- qualitative and quantitative methods to determine biophysical, cultural and economic benefits derived from ecosystems in a place-based context;
- information to support trade-off discussions in decision making, policy and planning including the appreciation of risks and opportunities associated with development options; and
- science- and social-science-based evidence of society's benefits and dependence on critical ES for human well-being (e.g., clean water, fresh air, and food).

An ES approach process and results can provide a broader range of values and benefits from wetlands, and this information is grounded in an assessment of what wetlands contribute to communities, to the region and to biodiversity and environmental functions.

---

[17] The cost of conducting each of the 33 local ES assessments included in the Millennium Ecosystem Assessment ranged from a total of $10,000 to almost $1 million. Costs depend on the methods used, the number of experts engaged and the activities conducted (MA 2005).

In this context, cumulative effects also includes the multitude of benefits provided by development, and not solely the cumulative negative impacts.

Importantly, the ES pilot work revealed that information assessed at a regional scale is just as important for supporting wetland decisions as site-scale information. The ES pilot undertook 21 site assessments using WESPUS, but also assessed four ES across the entire study site. The results of the regional-scale assessment showed that for some ES such as flood control, the position of a wetland within a larger landscape and how wetlands are connected on the landscape plays an important role in how the ES is produced and how effective it is. These findings suggest that proper planning for regional wetland management is crucial to maintaining or improving ES across the landscape.

One approach for developing relevant information to inform the wetland approvals process, especially with continued development, would be to perform regional assessments of ES on a regular basis (e.g., biannually), using the more advanced regional tools that were developed within the ES pilot, but not tested due to time constraints. The results of the pilot provide a baseline level of information about the wetlands, including losses and resulting changes in ES in the area. This information could be used in regional or sub-regional planning work on building thresholds. This would also allow for the identification of areas on the landscape that have the most value for specific ES. These regional assessments could also identify where people or development are most at risk from the impacts of ES loss. This information could support regional and long-term planning related to wetlands. Next, WESPUS site assessments could then be used to support decisions about specific wetlands during individual development applications, and wetland approvals decision makers can apply both the landscape-level and site-specific information to make informed decisions about the trade-offs associated with the proponents' application.

The discussion of cumulative effects and spatial issues is useful, but could be clarified somewhat from an economics perspective. Benefit cost analysis sometimes includes cumulative effects type input as part of the assumptions of project/ policy, size and scope, but this could be applied with more consistency. Decisions about the spatial extent of the analysis, the temporal dimension, and the underlying trends (economic growth, population growth, etc.) are all necessary for a thorough economic analysis.

Finally, a key value of the ES pilot for CEMs in Alberta is the enhanced credibility realized by involving multiple stakeholders in the process – as active members or as supporters on the periphery. The ES pilot involved numerous departments and organizations (e.g., municipalities, developers) that allowed for diverse perspectives, information and processes to be incorporated. For CEMs, this type of participatory approach can enable the development of new policies, processes and other opportunities that incorporate cumulative effects into decision making.

5.3 Alberta's Wetland Policy

In the fall of 2010, the Minister of Environment publicly released a document, building on previous work of the Alberta Water Council, outlining the intent to develop a provincial wetland policy that set an outcome to "to conserve, restore, protect, and manage Alberta's wetlands to sustain the benefits they provide to the environment, society, and the economy."

The intent document discussed wetland functions and listed for consideration the following wetlands benefits for Albertans: biodiversity, water quality improvement, flood reduction and human uses. A fifth consideration is abundance. It recognized the need for tools and knowledge systems to support decision making and policy implementation, including wetland assessment and mitigation guidelines.

The policy intent presented a number of challenges to address, including the need to:
- Address the diverse history, geography, land uses and wetland distribution across the province;
- Consider not only the individual wetland, but also regional significance and the relationship to other ecosystem components; and
- Take into account wetland function to ensure effective wetland management in Alberta.

Given the summary above and the results of the ES pilot, there are definitely aspects of alignment between these two important initiatives, particularly in information and methodology sharing. The ES pilot focused on developing assessment tools for some of the very functions that the policy intends to focus on. Additionally, the pilot presented a suite of other services and benefits received from prairie pothole wetlands both at an individual level (WESPUS) and at a regional level that could be more broadly applied across the province. The ES pilot has compiled numerous lessons learned on the process and methods applied, and can share important learnings about the place-based context of some of these functions and assessment challenges such as the scale 'mis-matches' between functions, benefits and wetland application differences.

With regard specifically to WESPUS, there is an interest both from ES pilot members and those working on the Wetland Policy to further explore the potential opportunities and weaknesses of an Alberta-WESPUS tool. Those working with WESPUS noted that it may be able to inform some important longer term policy questions for managing wetlands, such as:

- When is a compensation site good enough in terms of replicating value and/or function?
- How can multiple wetland functions be incorporated into wetland design?
- Have the functions and values associated with wetlands changed over time?
- After five to 10 years, is this compensation site considered "good enough" in terms of adequately replacing the lost natural wetland?

5.4 Land-Use Framework and Regional Planning

It is very important to ensure that assessments of ES are nested within other planning and policy work of the region. There is additional effort needed to link this small-scale pilot with the regional planning documents such as the SSRP outcomes. There are other scales of management and decision making, such as the Calgary Regional Partnership and the work of the Bow River Basin Council, for example, that could also incorporate ES-based information to enhance their relevance, credibility and legitimacy.

There are other opportunities to inform regional plans, both with the current SSRP and Lower Athabasca Regional Plan and new plans coming on board. In particular, planners could apply some of an ES approach at the outset of regional plan development. These could be powerful opportunities to ensure that multi-scale services and benefits are considered explicitly in regional plan design, capturing the ES that contribute to the quality of life for people in that region.

The information and specific methods for assessing wetlands and their benefits support the identification of wetlands as a valued component in planning processes and could be useful in setting thresholds and impact management objectives, and making trade-off decisions when other values compete with maintaining wetlands. From the perspective of the reports objectives that relate to providing information on wetlands to communicate their value, including the value to humans of maintaining wetlands on the landscape, the report is a valuable source of information. The report is relevant to the Land-use Secretariat (responsible for implementing the Land-use Framework) because it clearly shows that the reduced function and extent of wetlands in Alberta is a cumulative effects issue that is central to the Land-use Framework.

MASTER VERSION

5.5 Next Steps

In the immediate term, there are a number of steps that could be initiated to support continued progress on the ES road map. There are a number of short-term and longer-term steps that the AEW ES program should target to support the ES road map commitment for AEW to explore the adoption an ES approach. Continuing with the ES road map will support and enable AEW's work on cumulative effects management, policy development, planning, and decision making. The following are the key next steps as recommended by the team and vetted by the ES program leads.

5.5.1 Communication and Education

As the ES pilot wraps-up, the Communication Strategy developed will prioritize informing key stakeholders about the ES pilot intent, results and lessons for supporting existing and future provincial and place-based decision-making processes. There are two targeted audiences with two main objectives:

- Inform key audiences/stakeholders of the pilot on wetlands intent, scope and deliverables through a variety of communication approaches; and
- Identify opportunities to use results and learnings from the pilot on wetlands to further investigate and test the application of an ES approach to support place-based cumulative effects management.

The internal audience is defined as any Alberta Environment and Water or other Government of Alberta individual or team that has a direct stake and/or interest in the pilot on wetlands and/or can help identify opportunities/connections to other work. The external audiences are defined as individuals or groups external to government who have an interest in the pilot on wetlands, and/or are involved in ES assessments/initiatives (e.g. academics, environmental non-government organizations).

5.5.2 ES Road Map

The ES ten-year road map is progressing on its medium-term goals that include the pilot. The medium- and long-term goals are:

- *Medium-term goal (now-3yrs)*: The importance of ES is better understood and the department has increased its capacity for quantitative measurement of ES on the landscape to support policy, planning, and decision making within AEW
- *Long-term goal (3-7yrs):* A strong qualitative and quantitative capacity exists within the department to enable the ES approach to be common practice within AEW's policy, planning, and decision making processes.

The ES road map goals must be tied into other key priority areas of the Government of Alberta to ensure relevance and to ensure that limited resources are targeting the areas where the ES information can provide the greatest benefit.

Recognizing that the pilot was experimental in nature, the assessment can be built on to further strengthen the ES approach as a useful tool. While the regional assessment of the relevant ES and the WESPUS assessment of individual wetlands are complementary, it is not yet clear how the respective methods and results can be integrated into the decision-making/approval process.

From an understanding of the approval review process, one area that ES information could target is the planning stage, before approvals managers are asked to make decisions. If ES information could be presented in a meaningful way to developers so that they may consider it before submitting an application there may be improvements on how and where development is planned on the landscape. While this will not be an immediate change and may require a regulatory mechanism to oblige developers to act, AEW could work with municipal decision makers up front when a project is being conceptualized to see how best to work with the developer.

5.5.3 Government of Alberta Priorities

There are a number of areas, including the wetland policy and regional planning, upon which the ES program can focus its resources; however these resources are limited and the capacity to carry out ES assessments is still low. Therefore it will be extremely important to take a strategic view of where to focus resources, including support from the AEW sponsors and other Government of Alberta ministries.

While the ES pilot is set to finish in October 2011, there are a number of opportunities to further explore the ES road map and its objectives. This report presents the summary of the results only, but needs to be considered in the context of other reports prepared for the project such as the Lessons Learned report and the 'Methods' documents.

As noted previously it will be important to ensure that the interrelationship between ES and biodiversity is explored more fully within future Alberta studies. Alberta Sustainable Resource Development has led the drafting of a Biodiversity Strategy that will be a critical piece to inform this discussion. This process would be best served by the participation of not only Government of Alberta staff, but also stakeholders that have expertise in understanding these relationships, such as the Alberta Biodiversity and Monitoring Institute and Ducks Unlimited Canada.

5.6 Concluding remarks

The concept of ES is still in its infancy, but has been recognized globally as a useful tool for communicating the value of sustainable landscape management to support development and the long-term well-being of people. Ecosystem Services are becoming increasingly important for governments and business leaders to address in decision making. The Government of Alberta took a leadership role in advancing the ES road map and completing a pilot project to explore the incorporation of ES into an actual policy gap identified by municipal and government wetland approvals writers. This report represents the Integrated Results from the ES assessments and provides key findings and uses for the information generated. The ES pilot reports make up the platform from which to move forward on a number of opportunities to further improve understanding of ES, build capacity to assess ES, and provide more complete information to decision makers to improve the outcomes of their decisions.

Appendix A: References

Adamus, P. 2011. Manual for the Wetland Ecosystem Services Protocol for the United States (WESPUS) (Draft Version). Adamus Resource Assessment, Inc.

AECOM. 2011. *Shepard Regional Drainage Plan*. Report prepared for Shepard Regional Drainage Committee.

Agriculture Canada (AC). 2000. Prairie Agricultural Landscapes – a land resource review. Accessed at http://dsp-psd.pwgsc.gc.ca/Collection/A98-3-4-2000E.pdf

Alberta Agricuture Food and Rural Development. N.d., Agrisid 3.0: Accessed online: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag3254?opendocument#Background

Alberta Environment. 1993. Wetland Management in the Settled Areas of Alberta: An Interim Policy

Alberta Environment. 2006. South Saskatchewan River Basin – Water Management Plan. Accessed online: http://www3.gov.ab.ca/env/water/regions/ssrb/index.asp

Alberta Environment. 2008. Alberta Water for Life: Strategy for Sustainability: Renewal. Online http://www.waterforlife.gov.ab.ca/.pdf

AECOM. 2011. Shepard Regional Drainage Plan (Draft Version). City of Calgary, Rocky View County and Town of Chestermere.

Ash, N., Blanco, H., Brown, C., Garcia, K., Henrichs, T., Lucas, N., Raudsepp-Hearne, C., Simpson, R.D., Scholes, R., Tomich, T.P., Vira, B., and Zurek, M. 2010. *Ecosystems and Human Well-being: a Manual for Assessment Practitioners*. Island Press.

BCMAL (BC Ministry of Agriculture and Lands). 2006. Livestock Watering Requirements: Quantity and Quality. Order No. 590.301-1.

Badiou, P., McDougal, R., Pennock, D., and Clark, B. 2011. Greenhouse gas emissions and carbon sequestration potential in restored wetlands of the Canadian prairie pothole region. Wetlands Ecology and Management 19(3): 237-256.

Battin, T. J., S. Luyssaert, L. A. Kaplan, A. K. Aufdenkampe, A. Richter, and L. J. Tranvik. 2009. The boundless carbon cycle. Nature Geosci. 2:598-600

Bedard-Haughn, A., Yongbloed, F., Akkerman, J., Uijl, A., de Jong,E., Yates, T. and Pennock, D. 2006. The effects of erosional and management history on soil organic carbon stores in ephemeral wetlands of hummocky agricultural landscapes. Geoderma 135:306.

Boyd, J. & Banzhaf, S. 2006. *What Are Ecosystem Services? The Need for Standardized Environmental Accounting Units*. Resources for the Future. Washington.

Bridgham, S.D., J.P. Megonigal, J.K. Keller, N.B. Bliss, and C. Trettin. 2006. The carbon balance of North American wetlands. Wetlands 26:889-916

Brunet, N.B. 2011. Prairie Pothole Drainage and Water Quality. M.Sc. Thesis, Dept. of Geography and Planning, University of Saskatchewan, Saskatoon.

Canadian Honey Council. 2001. Pollination Value. *Hivelights*. Vol 14:4 pp.15-21. Accessed online: http://www.honeycouncil.ca/index.php/pollination_value.

Canadian Honey Council. 2009. Pollinating Hybrid Canola the Southern Alberta Experience. *Presented to the NSW Apiarist Association, State Conference*. Accessed online: http://www.honeycouncil.ca/documents/CanolaSthAB2009.pdf.

Cann, M., Dumanski, J., Brklacich, M., Kirkwood, 1992 The Impacts of Soil Degradation on Crop Yields in the Canadian Prairies: An Annotated Bibliography.Agriculture Canada. Accessed http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag11262

Chan, K., Goldstein, J., Satterfield, T., Hannahs, N., Kikiloi, K., Naidoo, R., Vadeboncoeur, N. and Woodside, U. (2001). Chapter 12. Cultural services and non-use values, pp 206-228 in Karieva, P., Tallis, H., Ricketts, T., Daily, G. and Polasky, S. (Editors) *Natural capital: Theory and practice of mapping ecosystem services*. New York: Oxford University Press.

CED. 2019. Home base: what drives head office locations and Calgary's place as a global business hub? Calgary Economic Development. Accessed online: http://www.calgaryeconomicdevelopment.com/sites/default/files/CED_HeadOfficesReportFINAL3.pdf

Chivers, V., Taylor, D., Pries, J., and Morley, I. 2011. Shepard Wetland: Largest Constructed Wetland in Canada. *Land and Water* (January/February). Accessed online: www.landandwater.com

City of Calgary. 2004. Calgary Wetland Conservation Plan. City of Calgary Parks. Calgary State of the Environment Report, 2006

City of Calgary and Rocky View County. 2001. The Shepard Plan. The City of Calgary Planning + Transportation Policy and Municipal District of Rocky View No. 44 Department of Planning and Development. 88 pp.

City of Calgary. 2007. Water Use Efficiency Plan. The City of Calgary Water Resources.

City of Calgary. 2009. Shepard Stormwater Diversion Project. Internal Summary Document. Received from Norma Posada-Flaherty, City of Calgary Water Resources.

City of Calgary. 2011. Ralph Klein Park. Accessed online: http://www.calgary.ca/CSPS/Parks/Pages/Locations/SE-parks/Ralph-Klein-Park.aspx

City of Calgary. 2011. City of Calgary Historical and Forecast Population Table. Accessed online: http://www.calgaryeconomicdevelopment.com/live-work-play/live/demographics

Cobbaert, D., Robinson, M., Trites, M., and Dam, A. 2011. An Assessment of Wetland Health and Values in Alberta's Industrial Heartland. Alberta Environment, Northern Region, Environmental Management, and Department of Biological Sciences, University of Alberta.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P., and van den Belt. M.. 1997. The value of the world's ecosystem services and natural capital. *Nature 387*: 253-260.

Cows and Fish. Nd. The Economic, Environmental and Social Value of Wetlands. Accessed online: http://www.cowsandfish.org/pdfs/value_of_wetlands.pdf

Creed, I., Sass, G., Buttle, J., and Jones, J. 2011. Hydrological principles for sustainable management of forest ecosystems. Hydrological Processes 25(13):2152-2160.

Creed, I. F. 2011. An ecosystem function based approach to quantification of ecosystem services of wetlands: water related ecosystem services (Proposal.). Irena F. Creed Consulting Services.

Creed, I.F., and Sass, G.Z. 2011. Tracking hydrological and biogeochemical processes through forested landscapes: Novel approaches using digital terrain modeling. In D. Levia (Editor), *et al.*, Forest Hydrology and Biogeochemistry: Synthesis of Research and Future

Cruickshank, Rob. 2011. Alberta Financial Services Corporation. Personal communication, Sept.16th, 2011.

de Groot, R., Wilson, M., and Bourmans, R. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics. Vol. 41, Issue 3, Pages 393 – 408.

Domestic Water Well Assessment. 2007. Final Report Domestic Water Welll Assessment and Monitoring Program Shepard Stormwater Diversion Project. Calgary: Waterline Resources Inc. January 19, 2007.

Dunn, Rob. 2011. Alberta Agriculture and Rural Development. Personal communication, July 26, 2011.

Environmental Protection Agency (EPA). 2011. EPA Greenhouse Gas Equivalencies Calculator. Accessed online: http://www.epa.gov/cleanenergy/energy-resources/calculator.html

Federation of Alberta Naturalist (FAN), 2007. The Atlas of Breeding Birds of Alberta: A Second Look. Friesens Printers, Manitoba. Pg 96.

Foley, J. 2007. *Calgary's Natural Parks*. Calgary Field Naturalist's Society.

Forrest, A.S.M. 2010. Created stormwater wetlands as wetland compensation and a floristic quality approach to wetland condition assessment in central Alberta. Master's Thesis, University of Alberta.

Gilbert, M.C., Whited, P.M., Clairain Jr., E.J., and Smith, R.D. 2006. A Regional Guidebook for applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Prairie Potholes. Engineering and Research Development Center, U.S. Army Corp. of Engineers, 170 pp.

Gordon, L., Finlayson, C.M., and Falkenmark, M. 2010. In: In Agricultural Water Management Volume 97, Issue 4, April 2010, Pages 512-519 Year: 2010

Government of Alberta. 2008. Land-use Framework. Accessed online: http://www.landuse.alberta.ca/AboutLanduseFramework/Default.aspx

Government of Alberta. 2009. Alberta Land Stewardship Act. Accessed online http://www.landuse.alberta.ca/AlbertaLandStewardshipAct/Default.aspx

Government of Alberta. 2010. Municipal Government Act. Online: http://www.qp.alberta.ca/documents/Acts/M26.pdf

Growth Management Study. 2008. Lovatt Planning Consultants Inc. http://www.rockyview.ca/LinkClick.aspx?fileticket=wC_JTo--wM8%3d&tabid=1000

Gustafson, A., Fleischer, S., and Joelsson, A.. 2000. A catchment-oriented and cost-effective policy for water protection. Ecological Engineering 14(4):419-427.

Haines-Young, R., and Potschin, M. 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D.G & C.L.J. Frid (eds.): Ecosystem Ecology: A New synthesis. Cambridge University Press, British Ecological Society, pp. 110-139

Hart, Andrew. 2011. Nature Calgary, Personal communication, June 17, 2011.

Hurd, T.M., Rynal, D.J., and Schwintzer, C.R., 2001. Symbiotic nitrogen fixation of Alnus incana spp rogosa in shrub wetlands of the Adirondack Mountains, New York, USA. Oecologia, IPT, 9-103.

Hvenegaard, G.T., Butler, J.R., and Krystofiak, D.K. 1989. Economic Values of Bird Watching at Point Pelee National Park, Canada. *Wildlife Society Bulletin*. Vol. 17(4). p. 526-31.

Inglewood Bird Sanctuary (IBS). 2011. IBS Staff, Email correspondence, September 27, 2011.

Intergovernmental Panel on Climate Change (IPCC). 2007. Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.*

Jiang, Bo. Rocky View County. Personal communication, Aug. 29th and Sept. 7th, 2011.

Kazmierczak, R.F. 2001a. Economic linkages between coastal wetlands and habitat/species protection: A review of value estimates reported in the published literature. Agricultural

Economics and Agribusiness Staff Paper.

Kadlec, R.H., and Knight, R.L. 1996. *Treatment Wetlands*. CRC Press/Lewis Publishers, Boca Raton, FL. 893 pp.

Kennedy, M. 2010. New Policy Tools for Conservation in Alberta's Boreal Natural Region. Accessed online: http://albertawilderness.ca/issues/wildlands/forests/boreal-forest/archive/2010-08-new-policy-tools-for-conservation-in-albertas-boreal-natural-region

Kerr, G., 2010. Personal Communication with Manager of the Ecosystem Services Program on previous work on SSRP.

Kumar, Pushpan, ed. 2011. The Economics of Ecosystems and Biodiversity. United Nations Environment Programme. Earthscan: London.

Leibowitz, S.G. and Vining, K.C. 2003. Temporal connectivity in a prairie pothole complex. Wetlands 23(1):13-25.

Millennium Ecosystem Assessment (MA). 2005. Ecosystems and Human Well-Being: Current State and Trends. Island Press, Washington, DC.

Manitoba Conservation, Environment Canada, Sask Water, 2000. Upper Assiniboine River Basin Study, Main Report. Manitoba, 125 pp. http://www.gov.mb.ca/waterstewardship/reports/planning_development/uarb_report.pdf

McAllistor, L.S., Peniston, B., Leibowitz, S.G., Abbruzzese, B., and Hyman, J.B. 2000. A synoptic assessment for prioritizing wetland restoration efforts to optimize flood attenuation. Wetlands 20(1):70-83.

McColl, Shannon. 2011. City of Calgary, Personal Communication, August 20, 2011.

Mitsch, W.J., and Gosselink, J.G.. 2000. The value of wetlands: importance of scale and landscape setting. Ecological Economics 35 (200) 25–33

Moore, T.L. and Hunt, W.F.. 2011. Stormwater Wetlands and Ecosystem Services. Urban Waterways Factsheet. North Carolina State University Press.

Murkin, H.A. 1998. Freshwater functions and values of prairie wetlands. Great Plains Research 8(1):3-15.

Nature Calgary website: http://birdcomp.fanweb.ca/locations_Langdon.html accessed on Aug. 30, 2011

Narayanan, A.V.S. 1986. Long-term on-farm economic effects of cropland erosion in the black soil zone of Alberta. Can. Farm Econ. 20: 27-37.

National Research Council (NRC). 2007. Status of Pollinators in North America. Accessed online: http://www.xerces.org/wp-content/uploads/2008/11/nas_pollinator_report_summary.pdf

NYC DEP. 1993. Draft Generic Environmental Impact Statement for the Draft Watershed Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply and Its Source. New York.

Picard, C.R., Fraser, L.H., and Steer, D. 2005. The interacting effects of temperature and plant community type on nutrient removal in wetland microcosms. Bioresource Technology 96:1039-1047.

Profile of the South Saskatchewan Region. November 2009. Government of Alberta. https://www.landuse.alberta.ca/Documents/SSRP%20Profile%20of%20the%20South%20Saskatchewan%20Region%20Report-P1-2009-11.pdf

RBC. 2011. Provincial Outlook Report. RBC Economics. Accessed online: http://www.rbc.com/economics/market/pdf/provfcst.pdf

Ranganathan, J., Bennett, K., Raudsepp-Hearne, C., Lucas, N., Irwin, F., Zurek, F., Ash, N. and West, P. 2008. Ecosystem Services: A Guide for Decision makers. World Resources Institute. Accessed online: http://www.wri.org/publication/ecosystem-services-a-guide-for-decision makers

Sauchyn, D., Byrne, J., Henderson, N., Johnson, D., Johnston, M., Keinzle, S., and Wheaton, E. 2007. Alberta Vulnerability Assessment: Assessment of Biophysical Vulnerability.

Saunders, P.R., Senter, H.F., and Jarvis, J.P. 1981. Forecasting Recreation Demand in the Upper Savannah River Basin. *Annals of Tourism Research*. Vol. 8(2). p. 236-256.

Schroeder, S. A., and Bauer, A. 1984. Soil water variation in spoil and undisturbed sites in North Dakota. Soil Science Society of America Journal 48(3).

Scott, Tracy. 2011. Ducks Unlimited Canada, Personal communication, Sept.21, 2011.

Soil Landscapes of Canada. 2006. Agricultural Data. Census Area: 798002. Agriculture and Agri-Food Canada.

Stirling, A. (1997). Multi-criteria mapping: Mitigating the problems of environmental valuation? Pp. 186-210 in Foster, J. (ed). Valuing nature? Economics, ethics and Environment. Routledge: London.

Strong, W. L., Calverly, B.K., Richard, A.J, and Stewart, G.R. 1993. Characterization of wetlands in the settled areas of Alberta. Alberta Environmental Protection, Unpublished report. Edmonton. 143p.

Thompson, Jonathon. 2011a. Personal Communication August 25, 2011

Thompson, Maggie. 2011b. City of Calgary, Personal Communication, August 4, 2011.

Verry, E.S., and Boelter, D.H., 1978: Peatland hydrology. In: Wetlands Functions and Values: The State of Our Understanding, P. Gresson, J.R. Clark, and J.E. Clark (eds.), American Water Resources Association, Minneapolis, MN.

Vitt, D., Halsey, L., Bauer, I., and Campbell, C.. 2000. Spatial and temporal trends in carbon storage of peatlands of continental western Canada through the Holocene. *Canadian Journal of Earth Sciences*, 37:(5) 683-693.

van der Kamp, G., and Hayashi, M. 2009. Groundwater-wetland ecosystem interaction in the semiarid glaciated plains of North America. *Hydrogeology Journal*, 17: 203-214.

Ward, F.A., and Beal, D. 2000. *Valuing Nature with Travel Cost Models: A Manual*. Edward Elgar Publishing Ltd. Northampton MA.

White, K. n.d. *Wetland Restoration/Constructed Wetlands*. Brookhaven National Laboratory, Department of Energy, University of Chicago.

Zedler, J. B., and Kercher, S. 2005. Wetland Resources: Status, Trends, Ecosystem Services, and Restorability. Annual Review of Environment and Resources, 30(1):39-74.

Appendix B: Glossary

Anthropocentric - A human-centered worldview (ethic); it sees humans as the source of all value (i.e., it is they who bestow value on other parts of nature), since the concept of value itself is a human creation.

Average Value - This refers to the value that results from dividing a total value of a natural resource for a particular use by the quantity of natural resource used.

Beneficiary (of Ecosystem Services) - Persons, groups or projects that benefit from ecosystem services in tangible or intangible ways.

Benefit - Positive change in human wellbeing from the delivery of ecosystem services.

Biodiversity - The variability among living organisms and the ecological complexes of which they are a part. This includes the diversity found within and between species and between ecosystems. Biodiversity serves as the foundation for all *Ecosystem Services*, which are dependent to some degree on the diversity of genes, species, populations, communities, landscapes and information, or on key components of biodiversity include food, genetic resources, timber, biomass fuel, and ecotourism.

Bog - A wetland characterized by peat deposits, acidic water, and extensive surface mats of sphagnum moss. Bogs receive their water from precipitation rather than from runoff, groundwater, or streams, with decreases the availability of nutrients needed for plant growth.

Cultural Services - The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values. (See also *Ecosystem Services, Provisioning Services, Regulating Services,* and *Supporting Services*)

Cumulative Effects - The combined effects on the environment arising from the combined impacts of all past, present, and reasonably foreseeable future human activities.

Driver (Direct, Indirect) - Any natural or human-induced factor that directly or indirectly causes a change in an ecosystem.

Economic Valuation - The attempt to elicit public preferences for changes in the state of the environment through analytical techniques where these preferences are quantified into monetary equivalents or other appropriate units. (See also *Valuation, Economic Value*)

Economic Value - The measure of the wellbeing associated with the change in the provision of an ecosystem service quantified in monetary or other appropriate units. It is not synonymous with monetary value. (See also *Benefit, Value*)

Ecological Functions - Natural processes that are necessary for the self-maintenance of an ecosystem and its integrity, such as primary production, nutrient cycling, decomposition, etc. (See also *Ecosystem)*

Ecological Process - A characteristic physical, chemical and/or biological activity that influences the flow, storage and/or transformation of materials and energy within and through ecosystems, such as the uptake of nitrogen from soil by vegetation.

Ecosystem - An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. (See also *Biodiversity, Ecosystem Services*).

Ecosystem Assessment - A social process through which the findings of science concerning the causes of ecosystem change, their consequences for human well-being, and management and policy options are brought to bear on the needs of decision-makers.

Ecosystem Services - Outputs (goods and services) derived from ecosystems that benefit people. These include provisioning services, regulating services, supporting services, and cultural services. Ecosystems, and the biodiversity contained within them, provide a stream of goods and services essential for society's well-being. It is synonymous with '*Ecosystem Goods and Services*'. (See also *Ecosystem Goods and Services, Provisioning Services, Regulating Services, Supporting Services,* and *Cultural Services*)

Ecosystem Services Approach - An Ecosystem Services approach provides a framework by which ecosystem services are integrated into public and private decision making. The approach included the following components: identification of problem or issue, identification of ecosystem services being provided, dependency and impact assessment, condition and trend assessment, economic valuation of services, identification of risks and opportunities, input into decision making.

Ecosystem Service *Dependency* - A project, plan or policy has a *dependency* on an ecosystem service if the service serves as an input or if it enables, enhances, or influences the conditions necessary for a successful outcome of the project, plan or policy. Projects, plans or policies that are dependent on ecosystem services are one type of beneficiary.

Ecosystem Service *Impact* - A project, plan or policy *impacts* an ecosystem service if actions associated with the project, plan or policy alter the quantity or quality of a service.

Fen - A wetland characterized by slow internal drainage from groundwater movement and seepage from upslope sources. Fens are characterized by peat accumulation, but due to the seepage of nutrient-rich water, fens are typically less acidic and more nutrient-rich than bogs. (See also *Bog, Marsh*)

Flow - Harvested provisioning ecosystem services for human use or consumption.

Groundwater Recharge - Inflow of water to a ground water reservoir (zone of saturation) from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.

Habitat - The natural home of a living organism. The three components of wildlife habitat are food, water, shelter.

Intrinsic Value - The worth of a good or service for its own sake, independent of the benefits they may yield to humans. (See also *Instrumental Value*)

Marsh - A water body covered by water for at least part of the year and characterized by aquatic and grass-like vegetation, especially without peat-like accumulation. (See also *Bog, Fen*)

Natural Asset - The stock of natural resources from which many ecosystem services are produced.

Opportunity Cost - The benefits forgone by undertaking one activity instead of another.

Provisioning Services - The products obtained from ecosystems, including, for example, genetic resources, food and fiber, and fresh water. (See also *Ecosystem Services, Regulating Services, Supporting Services,* and *Cultural Services*)

Public Good - A good or service in which the benefit received by any one party does not diminish the availability of the benefits to others, and where access to the good cannot be restricted.

Regulating Services - The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases. (See also *Ecosystem Services, Provisioning Services, Supporting Services,* and *Cultural Services*)

Resilience (of ecosystem) - The capacity of an ecosystem to tolerate disturbance without irreversible change in its outputs or structure.

Scenario - A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technology change, prices) and relationships. Scenarios are neither predictions nor projections and sometimes may be based on a "narrative storyline." Scenarios may include projections but are often based on additional information from other sources.

Slough - A marshy or reedy pool, pond, inlet, or backwater.

Stakeholder - A person, group or organization with a common interest in a project and its outcomes, where stakeholders may or may not be involved in the delivery of a project, and may or may not be an ecosystem services beneficiary.

Stock - The quantity or store of a natural resource from which provisioning ecosystem services are harvested, with the exception of carbon.

Supporting Services - Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat. (See also *Ecosystem Services, Provisioning Services, Regulating Services,* and *Cultural Services*)

Trade-offs - Management choices that intentionally or otherwise change the type, magnitude, and relative mix of services provided by ecosystems.

Threshold - The value of an indicator that reflects a problem condition in an ecological, economic, or other system. Thresholds at which irreversible changes occur are especially of concern to decision-makers.

Utilitarian - An approach that focuses on the satisfaction of human preferences. (See also *Utility*)

Utility - In economics, the measure of the degree of satisfaction or happiness of an individual. (See also *Utilitarian*)

Valuation - The process of expressing a value for a particular good or service in a certain context (e.g., of decision-making) usually in terms of something that can be counted, often money; can also be described in qualitative terms, using methods and measures from other disciplines (sociology, ecology and so on).

Value - Generally, the worth, merit or desirability of an ecosystem service to human. In economics, it is the measure of the wellbeing associated with the change in the provision of an ecosystem service. In social context, it is the appreciation or emotional value attached to a given ecosystem service.
It can be expressed quantitatively or qualitatively (either in economic terms or ethically). (See also *Benefit, Economic Value*)

Vulnerability - Exposure to contingencies and stress, and the difficulty in coping with them.

Well-being - A context- and situation-dependent state, comprising basic material for a good life, freedom and choice, health, wealth, good social relations, and security.

Wetland - Land saturated with water long enough to promote wetland or aquatic processes as indicated by the poorly drained soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to a wet environment.

Wetland Assessment - The identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities.

Wetland Compensation - Payment into a fund for wetland restoration work.

Wetland Inventory - The collection and/or collation of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities.

Wetland Loss - Includes infilling, altering, or physically draining a wetland, any impact to the riparian area or buffer strips, and any type of interference with the hydrology to and from a wetland.

Wetland Margins - The ordinarily dry land adjacent to a wetland (e.g. marsh, bog, fen, or pond) that depends on the presence of a wetland to provide water and habitat for plants and animals.

Wetland Mitigation - A process to reduce the loss of wetlands, focusing on avoiding loss, minimizing impact, and compensating for unavoidable wetland loss.

Wetland Restoration - The re-establishment of a naturally occurring wetland with a functioning natural ecosystem whose characteristics are as close as possible to conditions prior to its drainage or alteration.

Willingness-to-pay (WTP) - The maximum amount an individual would be willing to pay, sacrifice or exchange in order to receive a good or to avoid something undesired.